DEVELOPMENT, GROWTH, AND STATE OF THE ATOMIC ENERGY INDUSTRY

HEARINGS

BEFORE THE

JOINT COMMITTEE ON ATOMIC ENERGY CONGRESS OF THE UNITED STATES

EIGHTY-SIXTH CONGRESS

FIRST SESSION

ON

DEVELOPMENT, GROWTH, AND STATE OF THE ATOMIC ENERGY INDUSTRY

1959

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DEVELOPMENT, GROWTH, AND STATE OF THE ATOMIC ENERGY INDUSTRY

TUESDAY, FEBRUARY 17, 1959

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C.

The committee met, pursuant to notice, at 2 p.m., in room P–63, the Capitol, Senator Clinton P. Anderson (chairman of the Joint Committee) presiding.

Present: Senators Anderson (chairman), Pastore, Gore, Dworshak, Aiken, and Bennett; Representatives Holifield, Price, Van Zandt, Aspinall, Hosmer, Bates, and Westland.

Also present: James T. Ramey, executive director; John T. Conway, assistant staff director; David R. Toll, staff counsel; George F. Murphy, Jr., G. Edwin Brown, Jr., Richard T. Lunger, professional staff members; and Edward J. Bauser, technical adviser, Joint Committee on Atomic Energy.

Chairman ANDERSON. The committee will be in order, please.

Today we begin our public hearings for the purpose of receiving information concerning the development, growth, and state of the atomic energy industry as required by section 202 of the Atomic Energy Act of 1954. We have invited the Atomic Energy Commission to lead off the testimony today and approximately 30 representatives of industry and other interested groups and individuals will follow tomorrow and Thursday and on the 24th through the 26th of next week.

The main focus of the hearings will be on the civilian atomic power program and policies, but we will also cover a number of other related subjects affecting industrial development of atomic energy. Witnesses were invited to comment on the following additional subjects:

1. The program for nonelectric power applications for nuclear reactors, such as process steam and heating;
2. The declassification and dissemination of information;
3. The AEC's supporting services to the reactor industry such as feed material and chemical reprocessing of used fuel;
4. AEC contract policy in the reactor development field;
5. Isotope development;
6. Maritime propulsion program;
7. Organizational and administrative problems and bottlenecks in the AEC's reactor and industrial development field.

Today we are welcoming Chairman McCone in his first public appearance before the full committee since he became Chairman. I want to say that we have had very good relations since he became

Chairman, and I am looking forward to a constructive session of work in Congress.

It is my understanding the AEC will cover the atomic power program and policies generally in these hearings, and will discuss its proposed projects for fiscal year 1960 in our coming authorization hearings during the last week of March.

As you recognize, Mr. Chairman, after I dictated that, I found out when you called me this morning that the Commission had completed its program statement of projects for fiscal 1960, and we agreed that you might as well ascribe it at the end of your testimony here today. Therefore, I suggest that be done.

Incidentally, for the members of the committee I want to say that Chairman McCone has a preliminary statement that will run probably 40 minutes that will not deal very much with power except as to policies. After that is completed, if there are some general questions, we will move into this power question on which he has a more extended statement.

We expect to get our authorization hearings underway next week to consider AEC facility projects other than atomic power.

I am glad that we are considering the atomic power program early in this session. Last year, you may recall that on the initiative of AEC General Manager Fields and Mr. Ramey, our executive director, Chairman Durham agreed to postpone our hearings until June in order to permit informal discussions between the AEC and Joint Committee to resolve some of these issues. These discussions were helpful but time and personnel changes did not permit us to resolve all differences. I regret that the Commission this year has not yet seen its way clear to resume these discussions in any adequate fashion before we began these public hearings, but I recognize that the Commission has its problems in dealing with other agencies of the Government.

I had my say on the atomic power program in my opening statement before the Joint Committee on Friday, January 30, which I would like to put into the record, without objection.

(The statement referred to follows:)

STATEMENT BY SENATOR ANDERSON BEFORE JOINT COMMITTEE ON ATOMIC ENERGY UPON ELECTION AS CHAIRMAN

Today may be an appropriate time to make a few remarks to you on my hopes and plans as chairman of the Joint Committee on Atomic Energy for the coming 2 years.

But first I would like to say a word about Carl Durham's stewardship for the last 2 years. As you know, this position by law rotates between the Senate and the House. This shift could cause all sorts of problems and dislocations. However, it is a tribute to Carl Durham that he went to great lengths to consult and cooperate with all the Members (and that includes me) in the work of the committee during the last 2 years following my chairmanship from 1955–57. I look forward to giving the same kind of cooperation during the coming 2 years.

We have made considerable progress in the last 2 years. You may recall that Carl, in a speech at the nuclear congress in Philadelphia in March of 1957, set forth a six-point program early in his chairmanship. He recommended the following:

1. Authorize construction of a dual purpose plutonium reactor at Hanford.
2. Authorize development and construction of a flying prototype of a nuclear-propelled aircraft with a realistic target date for completion.
3. Substantially increase AEC funds for reactor development work.
4. Inaugurate an accelerated domestic reactor demonstration program.

5. Establish a vigorous foreign atomic power program.
6. Enact indemnity legislation.

I believe you will agree that we have made progress on that program. We have authorized the convertible Hanford reactor; have substantially increased reactor development funds; and have enacted the Euratom Cooperation Act and the Price-Anderson Indemnity Act.

The two places where we aren't doing so well on Carl's six points are the ANP program and the domestic atomic power program.

I will have more to say on the ANP program later, as well as our other military propulsion and weapons programs. I also hope we will jointly continue to consider our peacetime applications of nuclear power.

Today I would like to cover briefly my views on arriving at a basis for an expanded atomic power program which takes into account the views of the Joint Committee, AEC, and industry.

I am determined that a concrete, understandable program for insuring that this country takes its proper place in the development of the peaceful uses of atomic energy for power shall be enacted in this Congress. Obtaining this seemingly simple objective has been for several years like trying to catch the greased pig at the county fair. Every time we seemed to have our hands on it we found shortly it had escaped us.

Let me review the situation. Shortly after the passage of the 1954 act, several so-called first round stations were started—some entirely with private capital, some requiring certain Government help. This action by the electric power industry was heartening to all of us. But what happened after that? Some smaller and more experimental stations have gone forward, and many propositions and studies have started. Nevertheless, I cannot help but feel that the majority of these heavy expenditures by industry since the first round—and they are heavy for them—have not been sufficient to reach our main objective.

What, then, are the reasons for this industry lag? First, they do not feel an economic compulsion. Second, they have hesitated until recently to participate in an expanded program which would involve increased Government financial assistance and effort.

I hope I can understand this reluctance. Actually, the economic spur is lacking. We are not acutely short of power, nor the fuels to generate power. The cheapest fuel for power today is not nuclear fuel, but fossil fuel; and we have lots of coal, oil, and gas, and see a chance to develop new sources of energy in shales and lignites. They hesitate to ask Government help simply because they believe that what starts as help, once the Government has its money in the project, will end as Government control and ultimately Government ownership.

I have been pleased to hear the Chairman of the AEC (with whom I have been enjoying the finest of personal relations) suggest that we may be able to put aside for the present a solution to the question of public versus private power as it may relate to nuclear power. In that feeling and intent, I join him.

With that assurance, I feel we should be ready to go forward with a program, one with a time scale on it, one that real experts say will produce economical power; not today, but not in the dim and untimed future either.

Proposals for an atomic power program have received a great deal of study going back to the McKinney Panel in 1956, the hearings on proposed accelerated atomic power bill reported out by the Joint Committee in 1956, and the reports of the American Assembly and the National Planning Association in 1957. In 1958 there were the reports of the Edison Electric Institute, the AEC, and the Joint Committee staff report and industry's comments thereon. Finally in 1959 we have received the AEC ad hoc committee report, have held extensive informal seminars with all segments of the atomic industry, and heard Chairman McCone and the AEC Commissioners on Tuesday of this week.

As a result of all this study, review, and discussion, I believe there is general agreements as to the objectives of an expanded program. They are to achieve economic atomic power in some areas of the United States in 10 years, and earlier in Europe. By carrying on a program to achieve these objectives, we will help our overall goal of fortifying our technological leadership in the world.

There is admittedly some divergence as to methods of carrying on this program, but there is general agreement that greater Federal leadership and financial assistance will be required. Getting down more specifically, there seems to be much agreement and little disagreement to the methods laid out in the

Joint Committee staff report. Thus the AEC ad hoc committee endorsed the recommendation that first generation experimental prototype reactors be constructed by AEC under contract at Government sites. They pointed out that under exceptional circumstances private industry might be given an opportunity to build such a reactor. I would agree.

The staff report recommended that second generation prototype and large scale reactors be constructed by private industry under a somewhat more flexible power reactor demonstration program. In a talk on June 19, 1958, I suggested that we consider a grant covering up to 90 percent of the differential between the estimated cost of a nuclear plant and a conventional plant. I still think this is a good idea; but if we thus subsidize the building of plants by private utilities we must also find some comparable way to assist cooperatives and public power organizations (Federal, State, and local) through an extension of the second round power demonstration program or some other means.

The level of additional funding required for an expanded effort may require further review. The figures used by AEC and its ad hoc committee are not comparable with those used by the Joint Committee on Atomic Energy staff report. I am also afraid that when we get down to money, the Bureau of the Budget may still be a problem.

I have requested Mr. McCone to make arrangements for the AEC staff to resume discussions with our staff to see if a basis for agreement on power programs can be reached prior to the 202 hearings which begin February 17, 1959.

In conclusion, I would like to quote from my 1958 talk, which I deem particularly applicable today:

"I believe a program along the above lines would go a long way toward ending the stalemate which presently exists. As you know, I have always thought the so-called public power question was a phony in the atomic energy field. Our purpose is and has been to get reactors developed, built and operating, so that someday in the not too distant future atomic power will supplement conventional energy resources. At that time, the question of private versus public power may be relevant, but anything we do in the next few years will have little real effect when reactors can be bought off the shelf.

"In order for a program such as I have envisaged to work properly, there must be a considerable amount of 'good faith' involved. The good faith must exist between AEC and the Congress, and between the participating industrial and utility groups.

"In the past, there have been some questions as to the good faith of the executive branch and private organizations in this regard. This became manifest in the Dixon-Yates affair. Some of us have also wondered since whether private power organizations were not more interested in 'staking out' the atomic power field for private development than in the early achievement of economic nuclear power.

"I am willing to let the dead past bury its dead, and go on to happier days. There is certainly a need for a new era in atomic power development."

It is to this new era that I am now looking. Our purpose can be—I think must be—to make sure that the Nation which first used the force of the split atom as a weapon may continue its leadership in knowledge of what the atom can do, but direct the application of nuclear technology toward those uses which help humanity live in peace and plenty.

Chairman ANDERSON. Today Mr. McCone will state the Commission's position on the atomic power program and AEC's policies and proposals. The Commission staff has kindly made its statement available to us in advance, so we have had ample opportunity to study it and prepare our questions and discussion. Of course, that does not relate to the power part of the presentation.

Without prejudging it in its entirety, I would say it marks a step forward in its statement of objectives, and in AEC's assumption of leadership and direction in the planning of prototype development. I am disappointed in its provisions with respect to the construction of experimental prototypes, which will still apparently be regarded as the domain of industry, even for advanced concepts.

I have no reason to reverse my own feeling that for advanced experimental prototypes the AEC should take the risks and direct the

project, particularly where the Government puts up all or most of the money.

Now I know I will have a number of questions for Mr. McCone, and undoubtedly my colleagues will also. We have lived with this atomic power problem for such a long time that we may seem a bit impatient as newer hands take the helm in the Commission itself.

Mr. McCone has done a service by attempting to eliminate what I have called the phony public power issue in the atomic power debate. I hope he may be persuaded to display the same openmindedness on whether industry can and should build advanced atomic reactors in the same manner it builds conventional powerplants.

Since our objectives and some of our methods are the same, I hope we can resolve our other differences of opinion by reasonable accommodations of our methods, and get on with the job of getting some more reactors built and operating.

In fairness to Mr. McCone, I believe we should divide our questioning in two parts. First, when he finishes his statement on everything but atomic power. Then after he finishes on atomic power.

Mr. McCone, we are glad to have you with us today. You may proceed as you wish.

STATEMENT OF JOHN A. McCONE, CHAIRMAN; ACCOMPANIED BY WILLARD F. LIBBY, COMMISSIONER; HAROLD S. VANCE, COMMISSIONER; JOHN S. GRAHAM, COMMISSIONER; JOHN F. FLOBERG, COMMISSIONER; A. R. LUEDECKE, GENERAL MANAGER; PAUL F. FOSTER, DEPUTY GENERAL MANAGER; L. K. OLSON, GENERAL COUNSEL; F. K. PITTMAN, DIRECTOR, DIVISION OF REACTOR DEVELOPMENT; AND DON S. BURROWS, ALL OF THE ATOMIC ENERGY COMMISSION

Mr. McCone. Thank you very much, Mr. Chairman. I am pleased with this opportunity to appear before your committee and I would like to state that the experience in working with this committee in the 8 months that I have been Chairman of the Commission has been very gratifying and exceedingly pleasant. I have had the finest cooperation from you and from Mr. Durham and from all members of the committee, from Mr. Ramey and from the staff.

The Commission's testimony before the Joint Committee on development, growth, and state of the atomic energy industry, pursuant to section 202 of the Atomic Energy Act of 1954, this year will be in two parts. In order to avoid duplication, and with your permission, we would like to present for the record excerpts from the 25th semiannual report which describe the progress of industry in 1958 and related Commission activities.

(See AEC 25th Semiannual Report, January 1959, pp. 3–86, and appendix, pp. 230–282.)

My oral testimony for the most part will review first those matters other than the reactor program in which the Joint Committee has expressed special interest through Mr. Durham's letter of January 21, 1959. Afterward, I will present the Commission's plans for the most rapid feasible development of economic nuclear reactors for the generation of civilian power.

ADMINISTRATIVE CHANGES AFFECTING REACTOR DEVELOPMENT

An AEC-wide study on decentralization, affecting reactor developments as well as other programs, has been made. As a result, 22 delegations of authority were made to operations offices:

Operations offices, for example, were given responsibility for administering the access permit program, for promotions in upper grades, for giving assistance in radiation incidents, et cetera. On 18 proposals, action is pending to accomplish delegation, or to take other feasible action. Ten additional proposals were found to be not matters for delegation, and 46 were not accepted.

I would like to explain to the committee that we assembled the Division officers and managers and asked for their recommendations. In summary, they made a total of 97 suggestions as to steps which could be taken in the interest of decentralization and improvement of management, and the figures that I have just read were the results of this study which has been made and is continuing.

The Division of Reactor Development was reorganized. The Office of Industrial Development, except for isotope activities, was consolidated with the Reactor Division. This brings into a single division the important functions of planning and assisting industrial participation in the nuclear field, and the major civilian and military reactor programs that provide principal opportunities for industrial participation.

The Reactor Division's technical units were relieved of many administrative duties, and thus afforded more time for technical programs. Responsibility for all work of general applicability to more than one reactor type was placed under an assistant director for nuclear technology. This will give better balance in administration of the technical programs.

Early in the year the Pittsburgh Naval Reactor Operations Office was created and, together with the Schenectady Naval Reactors Operations Office, was assigned naval reactors work as its primary responsibility. The Lockland Aircraft Reactors Operations Office similarly was established with the aircraft nuclear propulsion program as its principal responsibility. Lines of communication, responsibility, and authority were shortened by these actions.

In carrying out the reorganization of the Division of Reactor Development, no significant change has been made in overall manpower devoted to reactor development programs.

CONTRACT ADMINISTRATION

The Commission took basic action during 1958 on establishment of fees for cost-plus-fixed-fee production and research and development contracts. The Commission confirmed existing practice of allowing a somewhat higher scale of fees for research and development work than for the operation of facilities. The Commission also recognized that the fee for operating contracts should reflect the research and development work carried on at each facility. The Commission adopted a moderately higher scale of fees for research and development work to be performed in private facilties, and confirmed the policy in such cases of reimbursing allocable home office expense separately from the fee.

For cost-plus-fixed-fee research and developmental contracts for operations in Government-owned facilities which are isolated from the contractor's private business, the Commission negotiates combined fee and home office expense arrangements. This provides for paying those specific expenses incurred at the home office which might otherwise be incurred at the site.

Discussions are being held with the Department of Defense with the objective of reaching agreement on a set of cost-reimbursement principles governing both Defense and Commission contracts.

The Commission has a firm practice of decentralizing contract approvals. There remain some contracts, however, which, because of their inherent novelty, may have to be negotiated in Washington. The power demonstration contracts are examples of such contracts, when the delineation of the program and the terms of the contract are intermingled and must be worked out simultaneously.

The Commission speeded up headquarters review of contracts negotiated in its operations offices. Responsibility for expediting review was placed in the general manager's office, and short but realistic deadlines were esetablished for each step. Under this system, reviews should be accomplished in 3 weeks, with 30 days the outside limit. This, I am told, is about half the time formerly taken before these changes were made.

The system is working very well. In January 1959 the Commission changed its disputes procedure. Use of an advisory board was abandoned and disputes now are referred to the Commission's hearing examiner. This should cut the elapsed time between filing of the appeal and decision on the appeal from the previous average of 18 months a case to something less than 3 months a case.

During the past year, the Commission made available to the public that portion of the AEC Manual which includes most of the policy and procedures relating to contracting and procurement, and contract article forms.

A public hearing was held on patent policies and written comments were obtained. Interim reports have been made to the Joint Committee, and recommendations will be made in ample time for committee study before your scheduled hearings later this spring. Among patent sections of the act which are receiving review is section 153 dealing with the authority of the Commission to declare a patent affected with a public interest.

TECHNICAL INFORMATION

The Commission declassified additional areas of information during 1958. Studies are underway to determine whether further categories of information can be made public without compromising national security.

I would like to read for the information of the committee some of the areas that were declassified in 1958. There was the controlled thermonuclear work, depleted uranium declassified and made available for use by industry, Federal material plants, plutonium fuel fabrication technology, and plutonium metallurgy.

Some 1,400 access permits were in force at the year's end, about the same number as a year previously, to allow use of certain categories of confidential and secret documents for industrial and commercial purposes.

Beginning January 1, the Commission ceased to provide investigations free of charge for the security clearances necessary for employees of access permittees other than nonprofit educational institutions.

Eleven technical books were prepared and published under Commission auspices during 1958, 6 information meetings were held, and 11 collections of papers presented at scientific and technical meetings were offered for sale. Twelve scientific works were translated from Russian, German, French, and Arabic. This was in addition to the publication during 1958 of 7,000 unclassified and 2,000 classified reports.

URANIUM PROCUREMENT

I wish to discuss briefly further actions taken by the Commission during 1958 to hold uranium production in reasonable balance with requirements while continuing to meet commitments incurred under previous purchasing policies and long-term contracts.

Canada began deliveries to the United Kingdom from ores committed to the United States but released for this purpose. An agreement was reached with South Africa placing a ceiling on its deliveries.

You will recall that in October 1957 it was announced that the Commission had decided to limit future commitments for the procurement of uranium concentrates that would involve the construction of new milling facilities. This decision was modified in April 1958 to permit a limited expansion of domestic milling capacty to provide markets in five areas having no market, or an inadequate market, for uranium ores developed prior to November 1, 1957.

Under this limited expansion program negotiations are substantially complete for concentrate purchase contracts that will provide an additional capacity of 1,750 tons of ore per day for the central Wyoming area. Completion of purchase contracts that will provide additional milling capacity for southeast Texas, North and South Dakota, and Nevada is awaiting further information to be supplied by the prospective contractors. Proposals for additional milling capacity for the Colorado Front Range have been submitted and are now under review.

On November 24, 1958, the Commission withdrew prospectively a concentrate purchase program for the 1962–66 period, announced on May 24, 1956. The Commission will carry out its commitments with respect to ore reserves developed prior to November 24 in reliance upon the announced program by negotiating contracts for the purchase, during the 1962–66 period, of appropriate quantities of concentrates derived from such ores. These contracts also will contain provisions designed to provide equitable treatment for independent miners, including a fair share of available mill capacity. With respect to ores developed after November 24, purchases of concentrates will be made at prices and terms to be agreed upon, as requirements dictate.

Milling capacity in the United States reached more than 21,000 tons of ore per day in December. Nine new mills came into operation; two were closed; in all, 23 mills were operating at the end of the year.

GROWTH OF ATOMIC ENERGY INDUSTRY

Next I would like to offer some highlights of the growth of the atomic energy industry during 1958.

Industry expenditures on power reactors, and purchase in this country of research and power reactors for installation in foreign countries, provided a moderate flow of business for private firms. Construction of all full-scale nuclear powerplants being built in the United States is privately financed. The total cost to private industry is estimated at about $300 million. During the fiscal year that will end June 30, 1959, private expenditures for construction and fabrication of such nuclear powerplants are expected to reach $70 million, compared with about $30 million the year before.

The chief sources of business for atomic industrial and research establishments, however, are the contracts of the Atomic Energy Commission and the Department of Defense. These contracts include design and construction of both civilian and military reactors, the latter chiefly for propulsion, for research and development in a variety of atomic energy fields, and for services and supplies for Federal atomic energy programs.

During the 1959 fiscal year, the Atomic Energy Commission and the Department of Defense together are expected to obligate about $570 million to reactor work, divided about 60 percent for military reactors and 40 percent for civilian reactors. Of this total, $420 million was by the Atomic Energy Commission. About $330 million of the total is principally for construction and fabrication of reactors, up about $60 million from the year before. Of this total, $155 million is being obligated by the Department of Defense and $175 million by the Commission.

There have been some cancellations in the power program during the year. The American and Foreign Power Co. announced the indefinite suspension of its plans to build small power reactors in Brazil, Cuba, and Mexico. The Pennsylvania Power & Light Co. and Westinghouse announced the withdrawal of their proposals to build a nuclear powerplant under the Commission's power demonstration program.

The Combustion Engineering Co. announced the acquisition of General Nuclear Engineering Corp. through an exchange of stock.

Power reactor developments contributed to a moderate expansion among supply and service companies of the atomic energy industry in the United States. Five additional companies undertook commercial atomic energy activities for the first time during 1958, performing such functions as processing of normal and enriched uranium, fabricating fuel elements, and disposing of low-level radioactive wastes. Four companies, already licensed to perform one service, undertook new lines of activity.

It is the Commission's policy to terminate its own services to industry when similar services become available from commercial sources. Expansion of commercial activity during the past year led the Commission to withdraw its previous offers to provide gamma irradiation, to end its encapsulation of high-intensity radiation sources, and to cease supplying a number of special materials.

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For the first time, during 1958, normal uranium could move in exclusively commercial channels from mines to finished products. The Commission continued as the sole source for enriched and depleted uranium, as it is for plutonium, and uranium 233.

All special reactor materials except boron 10 and heavy water now are available from commercial sources, as are all services required by the private atomic energy industry except neutron irradiation, chemical processing of irradiated fuel elements, and disposal of high-level radioactive wastes. Private industry has plans to operate two test reactors to provide neutron irradiation; one is already critical, the other nearly completed.

The Commission has invited proposals from industry to provide test reactor irradiation services to meet Federal needs, offering to contract for space in reactors for periods up to 5 years, subject to renewal. We received 11 proposals from industrial, research, and educational institutions, and these are being evaluated. It is Commission policy to build test reactors itself only if its needs cannot be satisfied at reasonable cost by commercial test reactors.

During 1958, the Commission removed restrictions from nonnuclear uses of uranium, and agreed to sell it on an unclassified basis; announced permission for private sale of uranium concentrates to authorized users here and abroad; filled out the schedule of charges for chemical processing of fuel elements; agreed to lease as well as sell heavy water for new research, medical, and testing reactors, and to consider leasing heavy water or waiving of charges for heavy water in certain power reactor programs. Plutonium-beryllium neutrons sources, formerly available only for research, were freed for commercial use.

No changes were made during the year in the Commission's pricing policies with regard to determining fair prices to be paid by the Commission for special nuclear material produced in non-Federal reactors.

The Commission has not changed from the general policy of recovering full costs for the materials or services it furnishes.

INTERNATIONAL MARKETS

Development of international markets is of vital interest, of course, to the U.S. atomic energy industry.

Export of the first power reactor to Europe from the United States was licensed during 1958, the 11,500 kilowatt plant for Mol, Belgium. Two U.S. companies were awarded contracts to build power reactors in Europe, a 15,000-kilowatt demonstration plant in West Germany which an American company will build in cooperation with a German affiliate, and a 150,000-kilowatt reactor for Italy.

A contract is being negotiated between a Swiss firm and an American company for a 16,000–27,000-kilowatt power reactor for Switzerland. American-built research, training, and testing reactors continue to sell abroad.

During 1958 contracts were awarded or bids solicited for 11 such reactors to be installed in 8 foreign countries. Foreign spending in the United States last year was estimated at about $35 million for reactors, nuclear equipment of various kinds, fuel element fabrication, and design and engineering services.

Not mentioned in this paper is one additional contract for a 180,000-kilowatt pressurized water reactor for Italy. The details of the contract have not been finally concluded and therefore it cannot be listed as a firm contract. However, it is one I do want to mention.

Chairman ANDERSON. Is that Edison-Volta, Mr. Chairman?

Mr. MCCONE. Yes, sir.

Seventeen bilateral agreements between the United States and individual nations, which are in force or awaiting ratification, provide for comprehensive cooperation in power reactor development.

Early this month, the Commission established a policy of making enriched fuel available to foreign countries on a 10-year deferred payment plan. This was in addition to similar arrangements previously made under the agreement with the European Atomic Energy Community, Euratom.

Countries and international organizations eligible under the new policy, those which have appropriate agreements for cooperation with the United States, would pay interest on the unpaid balance of charges for the fuel during the 10-year period. A limit is placed on the total available under this program. The total is in addition to that for Euratom projects, and will provide for projects with a combined generating capacity of no more than 500,000 kilowatts which can be completed by June 30, 1964.

The Commission and Euratom are prepared to issue invitations for reactor proposals shortly after the Euratom Agreement for Cooperation comes into force. In December, invitations for proposals under the joint 10-year research and development program were issued, and to date the Commission has received inquiries from 35 industrial organizations in the United States.

The Joint Committee is familiar with the details of the agreement which was signed in Brussels on November 8, 1958.

International groups are drafting plans for indemnification of public liability which might result from nuclear reactor accidents. The Commission, on request, is assisting in these efforts, and is working also on nuclear ship safety and on shipowners' liability for nuclear ships. The problem of liability has been considered an obstacle by some U.S. companies interested in selling or building power reactors abroad.

The Organization for European Economic Cooperation and the European Atomic Energy Community are drafting conventions; the International Atomic Energy Agency has appointed an expert panel on which the Commission's Associate General Counsel will represent the United States. The Commission and the Maritime Administration have been invited to assist in drafting amendments to the Brussels Convention of 1957 on the matter of a limitation of shipowners' liability for nuclear ship accidents.

As head of the U.S. delegation to the International Atomic Energy Agency's second general conference, held in Vienna September 22 to October 4, I assured the Agency of our country's full support. We made a number of proposals emphasizing (*a*) a major program of training, research, and application in the field of radioisotopes; (*b*) development of international safety standards; (*c*) an intensified fellowship program; (*d*) a research program under which U.S. financed research projects would be assigned to the IAEA for contracting to

research centers and universities throughout the world; (*e*) a long-range program to make nuclear power available to less-developed countries, and (*f*) IAEA's development into a major center for exchange of information and sponsorship of conferences.

While IAEA has successfully met most of its organization problems, as it moves into an operating program it is encountering new difficulties. We are assisting the Agency in overcoming these problems by such steps as providing financial support, offering expert personnel to work on key issues, and negotiating an agreement for cooperation.

LICENSING AND REGULATION

The Commission during 1958 improved and simplified its procedures and policies for licensing and regulation of the atomic energy industry. Protection of health and safety is, of course, paramount. Within that frame of reference, our basic concept has been to avoid a rigid pattern that might prove too restrictive or even unworkable in practice; instead the Commission has sought the maximum feasible degree of flexibility that is consistent with the public interest.

The Commission identified additional products such as industrial gages and quality control devices, which contain radioactive materials of sufficiently low level to be adaptable to use under general licenses when manufactured and distributed under a specific license. We also propose to exempt altogether from licensing certain other products containing small concentrations of radioisotopes.

Licensing of reactors currently depends on detailed evaluations of each proposed plant. Present regulations prescribe general standards and guides for reactor safety. To assist the designer, the Commission has been working toward the development of more detailed criteria pertaining to site selection, control rods, external containment systems, and control systems. We now have in preparation a revision of the reactor licensing regulations incorporating these criteria.

Pursuant to requests of the Joint Committee, we are preparing recommendations covering Federal-State relationships in the area of regulation and licensing. They will be presented to the committee in the near future.

Earlier in the year we established an Office of Hearing Examiner, to conduct hearings on matters assigned by the Commission. The hearing examiner reports directly to the Commission.

CONTROLLED THERMONUCLEAR RESEARCH

In the field of controlled thermonuclear research, scientists consider that they made progress during 1958.

At the beginning of 1958, efforts to attain a self-sustaining controlled thermonuclear reaction in ionized hydrogen gases had attained an effective temperature of only a few million degrees. At the year's end, effective temperature of the order of 10,000,000° had been achieved. Before such hot plasmas will produce more nuclear power than they lose by radiation, their energies must be raised by another order of magnitude—roughly to 100,000,000° effective temperature. New experimental machines are being designed and built.

Appreciable advances were made in instrumentation and diagnostic techniques. Improved measurements have led to a better under-

standing of hydromagnetic instabilities in the plasma and methods for controlling them. Attention is now being turned to the study and control of another form of collective behavior—plasma oscillations—that can give rise to coherent electromagnetic radiation in the radiofrequency and microwave regions, as well as to instabilities which reduce the length of time plasmas may be confined.

As a result of progress in mirrormachine technology, there is renewed interest in cooling of magnet coils as a means of reducing power loss in the coils and permitting the generation of stronger magnetic fields within the machines. Improved energetic ion and electron sources and plasma sources have been developed, and one form of radiofrequency heating, ion cyclotron resonance, has been successfully demonstrated on a small scale.

The United States and the United Kingdom completely declassified all information on controlled thermonuclear research. A number of the Commission's experimental machines were demonstrated at the United Nations Second International Conference on the Peaceful Uses of Atomic Energy in Geneva last September.

PROJECT PLOWSHARE

The Commission carried out a number of studies during 1958 on possible peaceful applications of nuclear explosives, an area of endeavor we have called Project Plowshare. Industrial concerns have shown interest in some of these. Three projects received preliminary consideration: Excavation of a harbor in Alaska, blasting of large masses of oil-bearing shales in which industry participation would be sought, and a fully contained explosion for manufacture of radioisotopes and generation of heat that might be tapped for power production. Also, mining companies have indicated interest in using nuclear explosives for low-grade ores or mineral deposits materials inaccessible by conventional methods. The studies, aimed at determining technical feasibility and economic desirability, give full attention to solving all health, safety, and conservation problems related to the proposed demonstration tests.

RADIOISOTOPES

Industrial use of radiosiotopes is continuing to expand. There were 23 percent more licensed industrial users in 1958 than in 1957. The quantity of isotopes shipped also increased—some 37 percent more curies of radioisotopes were distributed in 1958 than in 1957.

The Commission during 1958 got underway its program for assisting industry to make broader uses of isotopes and of high-intensity radiation.

The Joint Committee has seen the Snap III device—the small atomic battery powered with isotopes which converts the heat of radioactive decay directly into electricity. This is part of the military program of course—carried out by the aircraft reactors group of the Commission. Possible industrial uses of this device will be explored.

The Commission's activities designed to develop civilian uses of radioisotopes and high-intensity radiation have been assigned to the

Office of Isotopes Development, newly established to handle the broadened program.

The Commission in 1958 signed 25 contracts for studies to determine how isotopes could be used to assist various industries and for development work on potential uses already identified. In response to Commission invitations, more than 100 proposals were made by 50 industrial and 10 academic organizations. Training programs for industrial users have also been inaugurated.

Isotopes development is a relatively small program, so far as costs are concerned. The Commission hopes it may prove to have powerful leverage. Industry's savings from the use of radioisotopes have been estimated at some hundreds of millions each year. The potential is much greater than that. This program will seek to help develop that potential.

That concludes, sir, the first part of the program.

Chairman ANDERSON. Before you continue, perhaps we should pause for questions. While I have a number of questions I hope to ask, I am going to give others an opportunity first. I will ask one question. Then I will turn to Senator Pastore, and Congressman Holifield. I had two or three letters saying, "Will you ask the Chairman where we stand with reference to Russia?" They have been asking the Secretary of Defense where they stood with reference to missiles in connection with Russia. Would you want to comment at all on the general development of atomic power, peaceful uses, isotopes, particle accelerators, or whatever you wish?

Mr. MCCONE. Yes. I would like to give my views on some aspects of that problem. I had a number of discussions in Geneva and Vienna with Professor Emelyanov, who is the head of the Atomic Energy Authority in Russia. He told me in some detail about the 100,000-kilowatt plant which had been built east of the Urals, and had been put in operation. It is obvious to us at Geneva that this plant was primarily a plutonium producer, and that the production of electricity was a byproduct, and was not the principal reason for the construction of the plant. Professor Emelyanov gave me information that was somewhat different from that given to others from other sources. He said that he planned to construct 5 reactors of about 50,000 electrical kilowatt capacity each, and one of thirty or thirty-five thousand kilowatts in an area where they would be reasonably accessible to the technical people, and these would demonstrate the several different processes which he had in mind as being worthwhile of exploration. He promised to send me a paper explaining this program, but I never received that paper. However, it was apparent from my discussion with him that they are, as we are, exploring a number of different avenues of approach to this problem.

Deputy Prime Minister Mikoyan, when he was over here, made some remarks concerning their nuclear power program. What he said was—and this not to me, but it was repeated to me from good authority—that they had no immediate need for nuclear power. They had ample fossil fuel and an abundance of hydroelectric power. Therefore, they were going to engage in a deliberate but careful program of research and development in the interest of developing the best nuclear powerplants. This approach might in some way be verified by Emelyanov's statement that they had no interest whatsoever in sell-

ing powerplants outside of Russia. Their technicians were busy with their development program and they were not prepared to sell.

We have had some information from intelligence sources indicating very much larger programs than evidenced by these statements, and I am not purporting to deny the intelligence that has been reported which has spoken of a number of very large plants, although the particular individuals that I talked to indicated a somewhat different approach.

With respect to the icebreaker, as you know, that has been announced. I am told that it is in the water and that the nuclear reactor is being installed. We do not know and have no information as to when it will reach criticality.

I have no dependable information on their submarine program. The status of their nuclear-powered aircraft has been discussed with this committee. I have no doubt that they are working in both nuclear-powered aircraft as well as nuclear-powered submarines, and other naval vessels. The status of their development is not known to us.

Chairman ANDERSON. Thank you very much, Mr. Chairman. The committee received from Dr. Zinn a report after he came back, and I think it parallels in some respects the impressions you have on this program. If there is no objection we will put it in the record after the conclusion of your remarks. I think it has been published, but I think it is a good summation and agrees in a general way with the conclusions that you yourself reached when you were over there.

(The letter referred to will be found on p. 48.)

Rather than start questioning myself, I think I will start with Senator Pastore.

Senator PASTORE. Mr. McCone, several years ago when the so-called Gore-Holifield bill was before the committee for consideration, which provided $400 million for the construction of Government-owned reactors, the then Chairman of the Commission made the statement in opposition to the bill that we had not achieved a major breakthrough in the civilian power reactor field. Would you subscribe to that statement today?

Mr. MCCONE. I don't know just how to define a major breakthrough. I think that we have attained a number of major breakthroughs in the nuclear-powered field. However, in another light you might call them evolutionary advances. I think the fact that we designed the experimental boiling water reactor at Argonne for 20 megawatts of thermal heat, we have operated at 60, we are now putting a new core and making some modifications and are going to operate it at 100 megawatts, five times its design, is something of a breakthrough.

Senator PASTORE. Do you think that the American people are entitled to be a little more optimistic as to the potentiality of the peaceful uses of atomic energy today than they might have been a year ago?

Mr. MCCONE. Yes, sir; I do.

Senator PASTORE. I read in the newspaper not so long ago that we had achieved some major breakthrough on a small generator. I think it was labeled as 5 pounds. Will you tell us something about that? What was so major about that?

Mr. McCone. Unfortunately, I think your other duties foreclosed you from being at the committee meeting when I brought the device in. Everybody had a look at it. I think it was an important development, because it transformed the heat from a radioactive isotope into electricity with reasonable efficiency.

Senator Pastore. Mr. McCone, coming back to your international aspect, are you satisfied that the International Agency for the Peaceful Uses of Atomic Energy has lived up to all its expectations?

Mr. McCone. No; I am not.

Senator Pastore. Why are you not satisfied?

Mr. McCone. I think that it started under a very difficult handicap, because through the years when this country was making serious attempts to get it organized and was frustrated in doing so by Russia, we concurrently engaged in a number of bilateral treaties and also the Euratom arrangement. This has had a discouraging effect on the Agency. I think this is very regrettable. On the other hand, I do not see that—since the establishment of the Agency could be frustrated and delayed by the Soviets—we had any other course to follow than the one which the Secretary of State and the then Chairman of the Atomic Energy Commission elected to follow.

Senator Pastore. Do you think that the bilaterals have shown greater promise?

Mr. McCone. They have at this time; yes. I think, however, that we can very quickly establish a vitality in the Agency, and it is going to be an indispensable part of the use of the atom on an international basis.

Senator Pastore. The reason I ask you the question, Mr. McCone, is because I was one of those who felt the electrifying effect of the idea when it was first enunciated by the President in December 1953, and it did seem to bear so much promise, especially to the power-starved nations of the world. I remember I was at the United Nations at the time and everybody spoke so hopefully of it. For some reason we have not heard too much about it. You say here in your presentation under section 42, on page 14:

> While the IAEA has successfully met most of its organizational problems as it moves into an operating program it is encountering new difficulties.

Give us an idea of what some of these difficulties are.

Mr. McCone. Yes, I could do that. One of its responsibilities is the so-called safeguards, which is an expression that is applied to the accounting for and the disposition of the plutonium that is generated in a reactor. I found when I was in Vienna that despite the fact that the charter of the Agency charged it with the responsibility for administering safeguards, there was a wide divergence of opinion between the members of the Board of Governors of the Agency as to just how they should go about this, what they should do, or whether they should do anything at all. This is just one example, of which there are a great many others.

Senator Pastore. Do you think that it will serve any greater purpose than merely being a public forum for the discussion of some of the problems in research and development from a scientific, very technical nature, or do you think something substantial from a practical point of view will ever come out of this Agency?

Mr. McCone. I would hope that it would play a very important role in a number of areas. I can say this, Mr. Pastore. As the use of the atom grows, then we must have an international agency to handle it, because the consequences of the use of the atom know no international boundaries whatsoever. Therefore, the procedures and the manner in which it is used in one country are of very direct interest not only to the adjoining country, but maybe to the country that is removed by two of three states. For that reason we must have this Agency and we must encourage it.

Senator Pastore. In other words, you think it would be a mistake to discourage it.

Mr. McCone. I think if this Agency were to fold up, we would within a matter of 2 or 3 years by re-creating another one. That is why we have and will continue to give it every support that we can.

Senator Pastore. That is all, Mr. Chairman.

Chairman Anderson. Mr. Holifield.

Representative Holifield. On the point of the IAEA, how many people receive their salary from U.S. funds?

Mr. McCone. We pay salary to our Governor and he has a modest staff. I don't know how many. There are five or six. Then we make a substantial contribution to the overhead of the Agency itself, which is an international body, and I think we bear the same percentage of the overhead that we bear in the United Nations. I believe it is some 31 percent, although I am not sure of that figure.

Representative Holifield. I don't care to go into detail on this particular point at this time, but later on there will be an item in the authorization legislation, I suppose, to take care of our participation. There was last year something like $2½ to $3 million, as I remember.

Mr. McCone. Yes, there is an item in the budget this year.

Representative Holifield. I hope the Commission will be prepared at that time to justify our continuance in this organization. I think when our former colleague, Mr. Cole, was in Washington, he made a speech in which he was very critical of the fact that he was not being supported in the program and apparently he was quite discouraged from what is reported to have been said at that time. There is a lack of a program. There is a conflict between the program that they are ostensibly working upon, and the various bilateral agreements. In fact, it cast serious doubt on whether the Agency is justified or not on the grounds of what it is doing. So when you do come before the committee for authorization of the item I hope the Commission will be prepared to tell us what they are actually doing and what their plans are for the future, so that we can evaluate whether this is just an appendage of somebody's idea that is not working out, or whether it has something important to do.

Mr. McCone. We will most certainly do this, Mr. Holifield. I will say that there is room for a great deal of soul searching and examination of the Agency and the relationship between the Agency and this country. We have taken some very constructive steps, and I think some of the things that concerned Mr. Cole when he was over here have been rectified. It is far from perfect. I think it is worth continuing to work on, and I think we can answer the problems to your satisfaction.

Representative HOLIFIELD. I hope you can. I hope you can explain where they can do anything under the IAEA that they cannot do under the bilaterals. You say they have been successful in setting up their organization. Anybody can set up an organization. But when it comes to having an operating program that is a little bit different problem. The conflict seems to be that most of the nations want to deal on a bilateral rather than dealing in an international agency which is subject to the Soviet veto and subject to Soviet approval, you may so. You do have a more flexible arrangement through your bilaterals than you can have in your IAEA, or if it is duplicating an operational program, it seems to me that we are wasting money. If there are areas which are constructive and which can bring about results in the IAEA that you can't obtain under the bilaterals that is another problem.

Mr. MCCONE. I think the question of the fact that anything that goes on in one country in this field of nuclear power or the atom generally, might have serious effects on an adjoining country is a reason why it cannot all be done through either bilaterals or through regional arrangements, because you always come up to that borderline. There is a very interesting point, and that is that the General Electric Co. and the Brown Boveri Co. are to build a powerplant in Switzerland. It was 15 miles from the Austrian border. The Swiss Government proposed legislation similar to the one we proposed, only in a more modest level, to protect both companies from liabilty within Switzerland, but this did not protect them against liability if the damage was in Austria. This became what appeared to be an insoluble problem, so much so that Dr. Bavari came over to discuss it with us and others.

Representative HOLIFIELD. We will leave that at this time. I want to go back to the beginning of your statement where you say, the Commission adopted moderately higher scale fees for research and development work to be performed in private facilities. Do I understand that the Commission has raised its prices for research and development work over the standard which you had for doing it in your own laboratories?

Mr. MCCONE. No. The fees that we pay for research and development work done in a privately owned facility are somewhat higher than the fees that are paid to a contractor who uses our facilities. He has his investment and his capital at risk. It is in recognition of that that we have this somewhat higher fee schedule.

Representative HOLIFIELD. In other words, this is to reflect his investment in his facilities.

Mr. MCCONE. That is right.

Representative HOLIFIELD. At the present we will not get into patent policies. You have a very short paragraph on that, but that needs complete exploration at the proper time.

Mr. MCCONE. I felt we have not crystalized our policy and that should be a subject that we should deal with in this committee to the exclusion of other subjects.

Representative HOLIFIELD. In your treatment of the ore procurement on pages 6 and 7, you mentioned the fact that you have expanded to a certain extent our mill facilites in order to take care of ore development which occurred prior to a certain date under en-

couragement of the Commission. I think, of course, it is well that was done. I want to ask you this question: Are the ore producers on notice now in regard to any expansion of their production over the adjusted needs of the Commission? In other words, are we going to be faced with the same thing? Are they going to go ahead and develop large ore operations and then come in with a need for additional mills, or is this adjustment that you have made in the nature of a solution to commitments which the Commission made heretofore, but it more or less puts then on notice that this is it? In other words, this is the number of mills that are going to be utilized unless our needs change drastically.

Mr. McCone. I think our notice of November 24, 1958, that you refer to in paragraph 20, does just exactly what you have in mind. Prior to that announcement we had the exposure, because of earlier announcements, or perhaps being obligated to take ore that was developed. We were afraid that was an open-ended type of commitment that might prove very difficult to live with.

Representative Holifield. In other words, "Proposals for additional milling capacity for the Colorado front range have been submitted and are under review." Does that come under your prior decision?

Mr. McCone. No, that refers to a decision made in April of last year to provide a market in certain defined areas, the principal one being Wyoming, where there had been some ore developed, and there were no mills established to process that ore, and also there were the South Dakota and Nevada and southeast Texas areas. For that reason a limited expansion program was agreed upon with this committee, and it has been accomplished in the Wyoming area, and the other area that is under negotiation. That is not open ended. That is a very limited program, sir.

Representative Holifield. It is a limited program. We take into consideration our foreign purchases in setting that need?

Mr. McCone. That is right.

Representative Holifield. The agreement still stands between the Commission and the committee that before any extension of foreign ore purchases are made, there would be a conference with the committee on that point.

Mr. McCone. Yes, that is understood. There is a pretty close relationship with your committee on that.

Representative Holifield. I understand there was a meeting yesterday with the Subcommittee on Raw Materials. I did not have the opportunity of attending it. So this may have been taken care of at that time.

Mr. McCone. Yes, there was a meeting. I did not attend it, either. I understood there was a rather thorough discussion of the whole problem.

Representative Holifield. On page 10, in paragraph 30:

The Commission has invited proposals from industry to provide test reactor irradiation services to meet Federal needs, offering to contract for space in reactors for periods up to 5 years subject to renewal.

Can you assure the committee at this time that the prices for that space will be comparable with prices that are charged to commercial companies for the same time of space and service?

Mr. McCone. Yes, we can do that.

Representative Holifield. In other words, there is no intent on the part of the Commission to establish what you might call a two-price system, and in order to justify the building of these so-called test reactors, for the Commission to subsidize through a different type of price structure for services other than that paid by commercial users.

Mr. McCone. No, I think that will be very carefully policed, sir.

Representative Holifield. That is all of my questions.

Chairman Anderson. Senator Dworshak.

Senator Dworshak. Thank you, Mr. Chairman.

Mr. McCone, you were not a member of the Commission when the International Atomic Energy Agency was created. Therefore, I must recall that I was opposed to the establishment of that Agency on the basis that I could see no reason for setting up a counteroperating medium which could obviously do nothing which could not be done under the existing bilateral agreements. Now I am somewhat disappointed to learn of developments which indicate that my forebodings were probably justified at that time, and on that basis I should like to call your attention to paragraph 37 in your statement, where you point to a new policy being established, which will obligate the United States and AEC to furnish enriched fuel to foreign countries on a 10-year deferred payment plan, which is in addition to similar arrangements previously made under the agreement with Euratom.

Can you tell us what the significance of this new policy is?

Mr. McCone. Yes. Under the Euratom Treaty we are furnishing the fuel necessary for a million kilowatts, approximately, under a deferred payment plan. This was an incentive to encourage the building of plants which would be of American design and would be built in the six Euratom countries. It was the opinion of the Commission that we should have some authority and some arrangement to encourage some reactors in some non-Euratom countries, or in one or two instances projects which were not eligible under the Euratom arrangements. For that reason, we set aside that quantity of uranium.

Senator Dworshak. Do you think that AEC is justified in doing this without some approval by the Congress? Does it not make some commitments which may be far reaching and which may obligate this country and our Government to make extensive appropriations or grants or gifts to foreign countries for the development of nuclear power? I wonder if the United States has a responsibility to see that countries, even outside of Euratom, develop nuclear power. Do you think that you can justify that on the basis of the subsequent financial obligations you may be assuming without knowing that Congress will give approval to such a far-reaching proposal?

Mr. McCone. In the first place this program was discussed with the committee, Senator, the program as described in paragraph 37. I felt in voting as a Commissioner in favor of it that it was a reasonable thing for this country to do in view of our feeling that the promotion of this source of energy through American assistance was important in connection with our international affairs.

Senator Dworshak. That will be entirely outside of our participation in the International Agency. It will be outside of and in addition to our participation in the International Atomic Energy Agency.

Mr. McCone. Yes, until such time as an IAEA agreement is in force.

Senator DWORSHAK. Do you have any idea how much money will be involved so far as the commitments of our country are concerned in this new policy?

Mr. MCCONE. I do not have that figure at the moment. I can get it for you, sir.

Chairman ANDERSON. Would it not be about $50 million?

Mr. MCCONE. About $50 or $60 million.

Senator DWORSHAK. In addition to our participation in the Euratom program.

Mr. MCCONE. That is correct, sir.

Senator DWORSHAK. Over how many years?

Mr. MCCONE. It provides that the plants must be completed by June 30, 1964. So that would mean that they would have to be started at the latest at the beginning of 1962. The fuel delivered to them may be in 1963. It would be over 5 years.

Senator DWORSHAK. But it involves a 10-year deferred payment plan.

Mr. MCCONE. That is correct.

Senator DWORSHAK. That means we will receive nothing in payment for this enriched fuel within the 10-year period.

Mr. MCCONE. That is correct. We receive interest, of course, on the money.

Senator DWORSHAK. That is all, Mr. Chairman.

Chairman ANDERSON. Mr. Hosmer.

Representative HOSMER. Mr. McCone, in your statement thus far, you have indicated a concern regarding the international aspects of third party liability, which I share. I am wondering if something need be done to crystallize this problem and spur some kind of international agreement. I have in mind this sort of device. The Congress has the power to legislate the jurisdiction of our courts. I am wondering if we might limit or withdraw certain jurisdictions to entertain suits against our own contractors on the third party liability basis where they have been operating overseas and an incident occurs over there. Do you think some action such as that by the United States might push this thing along?

Mr. MCCONE. It may come to the point when some action of that kind will be necessary. The steps that are being taken now in the Agency and in the OEEC countries and Euratom, and so forth, might end up in a convention which would be satisfactory and would avoid legislative action.

Representative HOSMER. You have in mind the Swiss problem.

Mr. MCCONE. Yes; the Swiss problem. I think they resolved that. It might be better for one of my legal associates on the Commission to talk to this point because it is a very technical point. Do you have any comment on that?

Representative HOSMER. It may come to the point where something may have to be done in order to bring action on problems.

Mr. MCCONE. That is right, it might. I would not suggest that be considered at this time.

Representative HOSMER. As to another section of your statement, dealing with the Operation Plowshare, the Richfield Oil Co. in California has made several statements regarding the possible use of

atomic explosion in Canada. Can you give us any information on that problem?

Mr. McCone. Yes; Richfield has made a very exhaustive study of the possibility of using a small nuclear device under the Attabaska sands, feeling that the heat would crack the oil and make it more fluid, so that it would flow and make possible the pumping of it. We are very much impressed with their opinions, and they have been working very close with the Livermore Laboratory, as you probably know. We would like very much to see this experiment tried out.

I would point out that the oil reserves in the Attabaska sands are fabulous. They exceed—the proven oil reserves in Alberta—exceed the proven oil reserves in the Middle East. The only difficulty is that they have defied extraction and this may be a means of doing something about it.

Representative Hosmer. Of course, that will have to be a three-way effort between the company, the Atomic Energy Commission and the Canadian Government, I presume, would it not?

Mr. McCone. And the Province of Alberta, which has a certain autonomy in this area.

Representative Hosmer. I would assume that you are the only supplier of the device that could be used by Richfield, are you not?

Mr. McCone. That is correct.

Representative Hosmer. Do you need any authorizing legislation to supply a nuclear device for this experiment?

Mr. McCone. We cannot supply a nuclear device. I don't think we would need authorizing legislation to conduct the shot.

Representative Hosmer. You think you have authority to contract for the job, in other words?

Mr. McCone. The Richfield people have proposed to do all of the work themselves with their own funds. They wanted us to supply the device and to explode it for them, and I think that is within our authority. I would want to sit down and talk with this committee at the time, but I believe that is within our authority, just as it is within our authority to conduct the tests in Nevada, and to do other research.

Representative Hosmer. This is actually in another country.

Mr. McCone. That might present a question, Mr. Hosmer, that I have not quite thought through, as to whether it would necessitate some special permission from the Congress on that account. Although the Eniwetok tests are in another country, they are outside of the continental boundaries of the United States.

Representative Hosmer. They are under mandate from the United Nations, I think.

Mr. McCone. Yes.

Representative Hosmer. This is a rather exciting possible peacetime use of atomic energy, and I would imagine if it moved at all, it would move rather fast and those legal problems should be explored if there is any thought that we might have to do some special authorizing.

Mr. McCone. The timing of it, if it is to be done at all, is next winter, because it is impossible to get in over the tundra during the summer time. You have to wait until the country freezes up.

Representative HOSMER. So any authorization will have to be given by this session of Congress.

Mr. MCCONE. That is right. We will examine that. I am glad you brought that up.

Chairman ANDERSON. Would you supply to the committee any legal analysis you have made of this? It is quite different from the Eniwetok shot which is made for the defense of the United States. This is made to prove an oilfield for a private company which has a lease with another country. The expenditure of a million dollars might have different implications than what takes place at Eniwetok. I think it would be well for the Commission to furnish the committee with some sort of legal analysis. You might find, as Mr. Hosmer suggested, that you may need some special legislation.

(The information referred to follows:)

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., March 13, 1959.

Hon. CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy,
Congress of the United States.

MY DEAR SENATOR ANDERSON: During the recent hearing before the Joint Committee on February 17, 1959, the chairman discussed the possibility of a plowshare experiment in the Province of Alberta to examine the possibility of freeing oil from tar sands. During the discussion, Mr. Hosmer asked whether any legal problems would confront us in the carrying out of such a project and whether some form of special authorization might be necessary. You then asked that we supply to you a copy of any legal analysis which had been made on this matter.

I am attaching hereto as enclosures two such analyses. The first is dated February 10, 1959, by our General Counsel at the request of our Director of Military Application. The second, dated March 6, is a more detailed statement made subsequent to the hearing. As you will note, both conclude that such an experiment could be carried out under the existing law and without special authorization.

Sincerely yours,

A. R. LUEDECKE,
General Manager.

FEBRUARY 10, 1959.

OFFICE MEMORANDUM

To: Brig. Gen. A. D. Starbird, Director, Division of Military Application.
From: L. K. Olson, General Counsel.
Subject: Proposed use of nuclear energy to effect in situ recovery from McMurray oil sands of Alberta, Canada, Richfield Oil Corp.

I understand the Richfield Oil Corp. (subsidiary of Sinclair Oil Co.) has proposed to the Canadian Government experiments utilizing U.S. nuclear explosive devices to recover oil from certain McMurray oil sands located at Athabasca, Canada. Richfield proposes to pay substantially all costs involved. Under this proposal the devices would be detonated by AEC at appropriate spots in the limestone underlying these sands. The theory is that the heat and pressure thus created would crack the hydrocarbon in place and permanently reduce its viscosity so it can flow or be pumped to the surface. If effective, this would make available a large oil supply not economically recoverable by present-day conventional methods. I understand that officials of the Canadian Government have indicated to Richfield that the Canadian Government plans to ask the U.S. Government, through appropriate channels, to cooperate in the experiment. It is also my understanding that AEC would not be asked to, and would not, make any warranties as to the outcome of such experiments, or even that the explosions would accomplish the desired result.

Under these circumstances you have inquired (1) whether AEC has authority under the Atomic Energy Act of 1954, as amended, to cooperate in such an ex-

periment, and (2), if so, what kind of arrangements would have to be made with the Canadian Government.

(1) Under section 31 a. of the Atomic Energy Act, AEC may produce explosions for any reasonable purpose as part of a program of research and development. This includes research in connection with commercial applications of atomic energy such as that involved here. In fact, since the definition of research and development in section 11 v. includes demonstration projects, AEC could produce one or more explosions purely as demonstrations of a particular application even after completion of the experimental stage. Any or all such explosions may be produced under cooperative agreements with industry, government, educational institutions, or other persons. Also, the authority conferred by section 31 a. may be exercised in a foreign country as well as in the United States. Thus, if it is in the interest of AEC's own research program to obtain technical information or to demonstrate particular uses of atomic energy through projects conducted in a foreign country, and in the absence of contrary considerations of national defense and security, AEC has the legal authority to conduct such projects.

(This does not take into consideration policy questions such as the possible effect of experiments upon our test-ban negotiations with the U.S.S.R., or whether tests of this kind in Canada should be conducted by the United Kingdom using its own nuclear devices.)

Since the Richfield proposal contemplates use of nuclear explosive devices in a foreign country, and as these devices may be atomic weapons, one additional consideration should be discussed. Section 92 makes it unlawful for any person to "manufacture, produce, transfer, acquire, possess, import, or export any atomic weapon," except as provided in section 91. In view of this, and also to assure that there will be no compromise of restricted data, arrangements should be made with Canada whereby possession, custody, and control of the devices to be used in the experiments will be continually in AEC. This would involve, among other things, an agreement with Canada to permit entry of devices without customs inspection and not to interfere with AEC possession and control of the devices while on Canadian soil.

It seems clear from the above that AEC has the general authority to conduct experiments such as those proposed by Richfield. It should perhaps be emphasized, however, that this authority does not extend to the supplying of nuclear explosion services which have no part in an AEC research and development program.

(2) I understand that the proposed experiments, if undertaken, would be conducted pursuant to AEC's general authority described above and that as no restricted data will be communicated to Canada in connection with these experiments, it is not planned to negotiate an agreement for cooperation pursuant to sections 123 and 144 of the act.

It is recognized that a great many details will have to be negotiated with the Canadian Government before the experiments could actually be commenced. There will have to be resolved, among others, (1) questions as to the relationship of the United States and Canada on the project (the kinds of controls each country will have and how much information should be given to the Canadian Government); (2) the problem of liability to the public for possible damage from the explosions (as you know, the Price-Anderson Act is not applicable to nuclear incidents occurring outside the United States); (3) questions regarding waiver of Canada's customs laws and regulations with respect to the nuclear devices to be used; and (4) how AEC possession, custody, and control over the device will be maintained.

I cannot be certain at this time just what form United States-Canadian agreement on these and other relevant details would take, but I assume that this can be worked out between the AEC, the State Department and the Canadian Government.

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., March 6, 1959.

Memorandum for: Chairman McCone.
Subject: Plowshare experiments in Canada.

You have asked whether there is any provision in the Atomic Energy Act of 1954 which prohibits the Commission from conducting Plowshare program research or experimental detonations in the tar sands of the Athabasca-Fort McMurray area of Canada.

FACTS

We understand the facts to be as follows:

A nuclear explosive device built by the AEC would be detonated by the Commission as a research project to determine the feasibility of recovering oil by such means from tar sands. The Athabasca-Fort McMurray area has been chosen for this particular experiment because it is ideally suited to this research purpose. The project would be undertaken in cooperation with the Richfield Oil Corp. Richfield would reimburse substantially all the Commission's costs. These experiments would be undertaken with the consent and cooperation of the Canadian Government under circumstances and after execution of an agreement assuring that possession, custody, and control of the devices would remain exclusively and continuously in the Commission. Before proceeding we would ask for and receive complete assurances regarding security of the device and to preclude the unauthorized disclosure of restricted data incidental to transportation and detonation of the devices in Canada.

OPINION

It is my opinion that the project would not constitute a foreign distribution of special nuclear material under section 54 of the Atomic Energy Act or a "transfer by sale, lease, or loan" of such material under section 91. Furthermore, it would not be a publication of restricted data under section 142, and it would not be an exchange of restricted data under section 144. I conclude, therefore, that this project need not be undertaken under section 123.

The facts as presented enable me to conclude that this is a research project pursuant to the authority of sections 31 and 32 of the act. Section 31 a. authorizes and directs the Commission to arrange for the conduct of research and development activities relating to, among other things, the utilization of atomic energy for industrial purposes. This fits the instant case precisely. Section 32 authorizes and directs the Commission to conduct "through its own facilities" activities and studies of the types specified in section 31. A close reading of section 31 reveals it to be a broad grant of power to accomplish research objectives. The Commission is to "exercise its powers in such a manner as to insure the continued conduct of research and development and training activities in * * * [the specified fields] * * * by private and public institutions or persons, and to assist in the acquisition of an ever-expanding fund of theoretical and practical knowledge in such fields." This, together with section 32, which authorizes the Commission to undertake research in its own facilities "for these purposes," is proof of the mandate that the Commission develop peaceful uses and applications of atomic energy. I find no limitation which precludes the research now contemplated by the Commission. If Congress had intended to impose a geographical limitation on the Commission's research authority, it is reasonable to expect that it would have inserted the limitation in either section 31 or 32. It is not to be found there. Nor does any other section of the act preclude this experiment.

Accordingly, it is my opinion that the Commission has the legal authority to undertake the proposed Athabasca exepriments.

The fact that the Richfield Oil Corp. is also interested in these experiments, and will reimburse substantially all the Commission's costs, does not affect this conclusion. In fact, under section 33 of the act, if the Commission finds that private facilities or laboratories are inadequate to the purpose, it may conduct for other persons, "through its own facilities, such of those activities and studies of the types specified in section 31 as it deems appropriate to the development of atomic energy," and my determine and make such charges therefor as in its discretion may be desirable." Richfield's reimbursement of the Commission's costs in this case would be in the nature of charges under this section.

L. K. OLSON, *General Counsel.*

Mr. MCCONE. Yes. The same might be true in various ideas of the mining industry. We hear a great deal about the Athabaska sands, but one or two of the copper companies feel that we can go under a relatively low grade body of copper ore and shatter it with a device, and then leach the copper out and recover copper that otherwise could not be economically recovered.

Representative HOSMER. Mr. McCone, you mentioned the 100 megawatt plant that the Russians claim they have. I believe you saw that movie in Geneva that they had about it, did you not?

Mr. MCCONE. I did not see the movie, no.

Representative HOSMER. As I recall, the movie, among other things, declared that it was in an entire new location and an entire new city was then built around it. In showing some shots, they panned over to a window sill that looked like it must have been at least 50 years old, and would deny the fact that it was a new city. I am wondering if there are any discrepancies either in this claim or in other claims by the Russians that are unclassified that you can relate in these hearings?

Mr. MCCONE. We know of no reason to doubt that this plant was built in the manner and as shown in Geneva. Whether the background of it was camouflaged in some way, that I do not know. We have no reason to doubt that that plant is in existence and operating.

Representative HOSMER. It may be some of the ancillary details of the claim surounding it that might be in error.

Mr. MCCONE. Yes. They might have painted up the background a little bit or something like that.

Representative HOSMER. Regarding the Snap III thermoelectric device mentioned earlier, am I right in my recollection that that was done by contract, and only cost us $50,000?

Mr. MCCONE. It was done by a contract with the Martin Co. and the Minnesota Mining Co. I think the contract was $15,000. Is that right, Dr. Pittman?

Mr. PITTMAN. I am sorry. I don't have the figure with me.

Mr. MCCONE. It was $15,000 and done in about 3 months.

Representative HOSMER. I think that is a very remarkable accomplishment. If there is nothing else exceptional about it, the way it was done is certainly significant.

Mr. MCCONE. That little device will produce 20 times the amount of electricity that was produced by the batteries that were in the Atlas and would operate for 180 days, whereas the batteries in the Atlas operated for only 18 days, and weighed only one-fourth as much as the battery. So this has a very, very great importance as a means of energy in these space vehicles that we are talking about going forward with. This is a very important development.

Representative HOSMER. Does the Commission have any plans in regard to applying the thermoelectric principle on a large scale to a reactor?

Mr. MCCONE. I did not get the question, sir.

Representative HOSMER. Applying the thermoelectric principle on a larger scale to a reactor.

Mr. MCCONE. I am afraid that this principle has its limitations as to size, although we are now in the process of trying to develop a 100-watt unit wherein that one was 5 watts. I think we will be successful. Then we may carry it on to 1,000 watts. I feel that there is a practical limitation as to how far this can go.

Representative HOSMER. Thank you.

Mr. MCCONE. Mr. Chairman, I would like the privilege of correcting, if that $15,000 figure is wrong, because I don't think anybody here is exactly sure of it.

Chairman ANDERSON. Yes, surely. Senator Gore.

Senator GORE. Mr. Chairman, your statement confirms that the vast majority of expenditures in the field of the atomic energy agency have been made by the Government of the United States. Indeed, you say on page 8,

> The chief sources of business for atomic industrial and research establishments, however, are the contracts of the Atomic Energy Agency and the Department of Defense.

Under those circumstances, do you see any reason why private patent rights should be given to concerns for information, processes, and mechanisms about which it learns or which it develops as a result of Government contracts?

Mr. MCCONE. No. I would like to reserve a discussion on this patent matter until we have had an opportunity to thoroughly review the subject. However, I feel in this area, as I have felt in defense contracts in prior years where I have had a responsibility, that where Government funds are involved, the developments should go into the public domain. This I think is a valid principle.

Senator GORE. I welcome that indication of your attitude, and I trust the majority of the Commission will share that view. But since you wish to defer detailed discussion I shall desist. Thank you, Mr. Chairman.

Mr. MCCONE. I would like to point out in support of that statement that the military expenditures in 1959 were $369 million and civilian $209 million, a total of $578 million.

Senator GORE. All of which were made under Government contracts.

Mr. MCCONE. That is correct.

Senator GORE. Thank you, Mr. Chairman.

Chairman ANDERSON. Mr. Price.

Representative PRICE. Thank you, Mr. Chairman.

Mr. McCone, in your statement, you state that the United States and the United Kingdom completely declassified all information on controlled thermonuclear research. Does this mean that all the information is now declassified and now available, or that it has been completely declassified, but the process of making it available has not been completed?

Mr. MCCONE. It has been completely declassified and is in the process of being made available. There is a little problem of mechanics, Mr. Price, because much of the information, or a great deal of the information that we were declassifying was contained in reports and commingled with highly classified information that came out of the laboratories. We, therefore, had to go through a rather tedious process of segregation and that is drawing to a conclusion. So the only information that has not been put in the public domain is that which just the mere mechanics of getting around to it has presented.

Representative PRICE. Does that mean that information as it develops now in research is born declassified, or if it is born classified, it is later declassified?

Mr. MCCONE. It is born declassified.

Representative PRICE. I would like to refer to Project Plowshare, in which you state that three projects received preliminary consideration. This is in paragraph 53 on page 17. You said received preliminary consideration. You don't say are receiving preliminary

consideration. Does this indicate that they are being held in abeyance or that they are active projects at this time?

Mr. McCone. We are seeking an alternate to the harbor in Alaska because, as I said to this committee once before, we couldn't find a customer for the harbor.

Representative Price. Had you selected a harbor?

Mr. McCone. I had not, no.

Representative Price. Had the harbor been selected? Did you have a specific location for the harbor?

Mr. McCone. No. The location was spotted in Alaska which seemed to lend itself to this type of an excavation, and the result would be a harbor. There seemed to be some question of whether once excavated there would be the need which would support the building of the piers and all the rest of the things.

Representative Price. Wasn't there some question about its future commercial use?

Mr. McCone. That is right. So we have turned our attention to some other possibilities which would demonstrate exactly the same thing, and might be more useful. That is why there is a qualifying phrase in this particular paragraph.

Representative Price. It is just one of three that you mentioned here. What about the others?

Mr. McCone. The oil-bearing shales is under very active discussion. There is no hesitation about going forward in that respect. There was a very important meeting in Dallas just within the last 2 weeks discussing the oil-bearing shales. I differentiate that from the Attabaska sands which was not mentioned in this paper. Then there is the underground explosion in the salt dome which has been under active discussion for some months with the Governor of New Mexico and his staff, and there is no reason why at the proper time that should not go forward.

Representative Price. I notice that the chain of communication between yourself and members of another committee in the House on this oil-shale project. Would you elaborate on that?

Mr. McCone. I don't recall.

Representative Price. I think it had something to do with whether there would be any commercial oil developed from these experiments.

Mr. McCone. I don't recall that controversy. There was some question of safety which was brought up, and also some questions arose with the Department of Interior who have cognizance in this area. I have discussed that with Secretary Seaton, and there is no problem there.

Representative Price. I would like to go back to the thermonuclear point again. I would appreciate if you would elaborate on the purpose of the new steering committee which has been set up to review the Sherwood program and what its objectives are.

Mr. McCone. I wonder if I could ask Dr. Libby, who is very intimately associated with this, to answer. Would that be satisfactory with you to ask Dr. Libby to answer that question?

Representative Price. Yes.

Dr. Libby. Congressman Price, we have felt that the project has been so big and so urgently carried forward that now would be a good time to get a committee to review its objectives and its progress.

Dr. John Williams, director of our research, who is here, has been seeing that this review was undertaken. The point solely is one of good management and making the maximum progress. In an effort of this sort, it is necessary frequently to take stock. The best people to take stock are the experts in the field, and that is the way this committee is constituted. Dr. Williams could give you more detail about its actual deliberations.

(The membership of the committee referred to above has been supplied by the AEC, and is as follows:)

In working toward a reassessment of the controlled thermonuclear program, we have enlisted the aid of the newly appointed members of the Sherwood Steering Committee consisting of:

Dr. Norris Bradbury, director, Los Alamos Scientific Laboratory.
Dr. Henry Smyth, Princeton University.
Dr. Edward Teller, director, Lawrence Radiation Laboratory, Livermore.
Dr. Alvia Weinberg, director, Oak Ridge National Laboratory.
Dr. S. Chandrasekhar, University of Chicago.
Dr. W. Fowler, California Institute of Technology.
Dr. R. R. Wilson, Cornell University.
Dr. A. E. Ruark, Chief, Controlled Thermonuclear Branch, AEC.
Dr. J. H. Williams, Director, Division of Research, AEC.

This standing committee is making a review of the controlled thermonuclear research activity, both present and planned. Their advice will serve to aid in determining our future program.

Representative PRICE. Mr. Chairman, I think you have covered pretty well everything in your report except the subject of aircraft nuclear propulsion. Would you like to add a paragraph in the report on that subject?

Chairman ANDERSON. It comes as a great surprise that Mr. Price would ask about that.

Mr. MCCONE. Yes.

Senator GORE. And also that reference to the project be omitted.

Mr. MCCONE. We, as you know, have the responsibility for the development of the reactor. I don't have to tell you about this because you know a lot more about it than I do, Mr. Price. We have in the fiscal 1960 budget about $75 million to be divided between the Pratt & Whitney project and the General Electric project, with approximately two-thirds of the money going to the General Electric project.

The Air Force have about $75 million in their budget. Our rate of expenditure is about the highest level that we can accomplish with the Air Force's level of expenditure. In other words, the two are reasonably compatible.

Representative PRICE. But if the Air Force level were raised, your Reactor Division was in a position of practically recommending that you would increase your efforts.

Mr. MCCONE. If the Air Force raised their rate of expenditure, which they would do if they decided to immediately initiate the building of the prototype aircraft and would concurrently place greater effort on their engine development, then this would call for greater expenditure from us. That increased expenditure would be of the order of $25 million a year more on the General Electric program which supports the Air Force program, an additional $25 million, plus or minus a few million through the years, is about the maximum level of expenditure that we feel that we can make and bring forward the

technology and the developments in the areas of reactor physics and materials which are a function of time as well as money spent. However, we feel that will bring the program forward as rapidly as the Air Force can go forward with the development of their airframes. So we do not think that the program under any agreed tempo of development would be delayed by the Atomic Energy Commission's program.

Representative PRICE. You don't delay it as far as the reactor end of the program is concerned.

Mr. MCCONE. No; that is what we expect. I would point out to you, as you know so well, that we are moving into a new field here, and there are some problems of materials and reactor physics that look very encouraging, but still are subject to some considerable further development.

Representative PRICE. Do you feel that it is possible at the present state of the art to develop a reactor within 3 years or 4 years that would be available for a flying test prototype?

Mr. MCCONE. Yes; there is no question about that.

Representative PRICE. What figure would you put on? Would you say 3 years?

Mr. MCCONE. I hate to say as much as 3 years. It seems a long time. I think 3 years is a reasonable minimum estimate.

Representative PRICE. That would be a minimum?

Mr. MCCONE. Yes; I would think so.

Representative PRICE. Do you mean by that that you could do it in 2 years if you put a little more effort into it?

Mr. MCCONE. No; I don't think so, sir. I would not like to say that. As I mentioned, there are some problems of research, and particularly in the area of materials development for these fuels elements to handle these extremely high temperatures. They not only have to be developed but then they have to be tested, and this testing takes quite a period of time. So the most informed people seem to defend the 3 to 4 years as a logical period.

Representative PRICE. Haven't there been recommendations at times—I won't be specific on time—from the Reactor Division of the Commission along the line urging early flight for a flying test so that they could prove out the theory of the nuclear propulsion reactor?

Mr. MCCONE. Yes. As I understand it—and I have been rather removed from this for a number of years, although I was close to it when I was Under Secretary of the Air Force in 1950–51, and have not been associated with it until recently—there were two schools of thought. One was to build a reactor that could be installed in an existing plane to serve just as a flying test bed, to prove and demonstrate the feasibility of nuclear propulsion of flight. The alternate approach was to build the reactors into a specially designed, specially constructed test airplane, which would have reasonably useful characteristics, and therefore would demonstrate a plane which might be an acceptable military unit.

Representative PRICE. The overall field of shielding was one of the problems involved. Would you say that progress in experiments over the last few years has been such that it no longer is a deterrent toward an early flight?

Mr. McCone. There is a great deal of development work to be done. We feel that development work can be carried forward and the answers can be successfully reached by the time that the program is ready. I would not like to leave you with the impression that the Commission feels that the shielding problem is solved. It is not solved, in our opinion.

Representative Price. That is all I have, Mr. Chairman.

Chairman Anderson. Mr. Bates.

Representative Bates. Mr. Chairman, about a year or so ago before I was on the committee, I talked to several people who were interested in this field, and they made several complaints of problems that they faced as they tried to develop their own work in this area, among which were third party liability that was discussed somewhat today, and also patents. I understand your recommendation on that will be here in the spring.

Mr. McCone. That is correct.

Representative Bates. The other thing was the question of finances. They thought it was a good way to lose some money, to get into this particular field. Apparently a good many got in shortly after the war and a good many got out. In this contract administration, I notice you have a moderately higher scale for research and development contracts than you had previously, is that correct?

Mr. McCone. That is right.

Representative Bates. Does that mean now that they are going to lose money more slowly or will they break even, or what is that level now?

Mr. McCone. I don't think companies have lost money on Atomic Energy Commission contracts, particularly their fee contracts.

Representatives Bates. Their what contracts?

Mr. McCone. Their fixed fee contracts.

Representative Bates. No.

Mr. McCone. They have not lost money. They have not made as much profit as they might have liked, and they have criticized us for being rather niggardly in the level of fees. There is some indication that our fees are much lower than fees in some Defense Department areas. I am not prepared to say whether that is a correct criticism or not. I think the problem that you refer to is that which companies have encountered who have gone into rather extensive development of organizations and of facilities with the idea that there was just an enormous horizon of business, and because it turned out that nuclear power was harder to come by than we thought it was going to be, this business has been slower to develop, and these people have suffered from the want of business and therefore they have lost money. This is true of a great many firms.

Representative Bates. I think that is about the situation as it was described to me. But many of them have since retired from the business.

Mr. McCone. Not so very many, sir. I could get you the statistics on it, but not so very many.

Representative Bates. Are they negotiated contracts?

Mr. McCone. There are various kinds. Some of them are negotiated. Some of them are selection contracts in which a contract review board reviews the qualifications of the prospective contractors

and makes a recommendation to the General Manager, and at certain levels of size they come before the Commission for decision.

Representative BATES. What format do you follow? Do you follow the regulations of the Armed Services Procurement Regulations?

Mr. MCCONE. We have our own.

Representative BATES. Did you write your own?

Mr. MCCONE. Yes.

Representative BATES. Were those part of the original law? In other words, how did you come to the point of writing your own?

Mr. MCCONE. I was not here so I can't tell you that. I can get that information for you. I will say that I have been impressed in my study of our contract procedures with the exactness to which it has been carried out by the Commission. It has been an evolutionary matter that started back in the old Manhattan District when they first built Hanford and Oak Ridge, and has developed through the years. It is quite well done. I would like to have the privilege of giving you the details of it and the background of how it developed.

Representative BATES. I wish you would put something along that line in the record.

Mr. MCCONE. Yes, sir.

(The information referred to follows:)

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., March 6, 1959.

JAMES T. RAMEY,
Executive Director,
Joint Committee on Atomic Energy,
Congress of the United States.

DEAR MR. RAMEY: During the course of the 202 hearings before the Joint Committee on February 17, 1959, Congressman William H. Bates requested the Chairman to submit for insertion in the record a statement as to the evolution and development of the Commission's procurement and contracting policies and procedures. This letter responds to that request.

In 1947 when the responsibility for the Nation's atomic energy activities was transferred from the Manhattan Engineer District to the Commission, the Commission operated almost exclusively under the policies and procedures theretofore established by the MED. In at least one important area we have continued to follow contracting practices which had their genesis in the MED days. I refer to the practice of contracting with industrial concerns and academic institutions for the performance of the actual operations of the Commission. However, in the main the Commission's procurement and contracting policies have been developed by the Commission itself. Thus, in December 1950, AEC formulated and confirmed the general principles of its contracting policies and issued them as the "AEC Procurement and Policy Guide" which was published in the Federal Register and Code of Federal Regulations (10 C.F.R., pt. 5).

The procurement and policy guide sets forth basic contract and procurement policies. It does not contain detailed procedures or instructions except to the extent necessary to establish the basic policies. However, the detailed procedures and instructions were described at some length in the Commission's 9th semiannual report published in January 1951. In addition, the procedures were contained in various manuals and in a series of issuances known as General Manager bulletins.

In 1952 the Commission undertook to bring together under one cover all of its procurement and contracting policies and procedures. The product of this effort was one full volume (vol. 9000) and portions of other volumes in the AEC Manual. This manual supersedes the older General Manager bulletins. It is in looseleaf form and is constantly undergoing revision and refinement. The AEC Manual is, of course, on file with the Joint Committee, and revisions are filed with the Joint Committee as they are issued.

The basic authority for the Commission's procurement policies stems from the Atomic Energy Act. However, many facets of our procurement and contracting

procedures are governed or affected by general overall governmental requirements contained in (*a*) basic procurement statutes (e.g., sec. 3709 of the Revised Statutes relating to procurement by advertising), (*b*) such statutes as the Small Business Act and the Defense Production Act, and (*c*) decisions of the courts and the Comptroller General. And, while the Commission's procurement and contracting activities are not carried on directly under the authority of the Armed Services Procurement Act or the Federal Property and Administrative Services Act of 1949, in the interest of achieving maximum uniformity in Government contracting, our detailed procurement and contracting instructions and procedures are substantially consistent with these statutes and the regulations promulgated thereunder, namely, the Armed Services Procurement Regulations and the General Services Administration Regulations.

Sincerely yours,

A. R. LUEDECKE, *General Manager.*

Representative BATES. On page 9 in reference to cancellation of some of the power program, especially the ones in South America, what were the circumstances that brought those about?

Mr. MCCONE. I think the South American programs were canceled by the American & Foreign Power Co. because of the realization that small powerplants were expensive, and that the power produced was quite high cost. Therefore, the inducement that they thought was there in the excitement of the early days was not there. For that reason they dropped it. It may be that some of the uncertainties of foreign investment disturbed them as well. That I do not know.

Representative BATES. What is the cheapest plant that is being built for a foreign country in terms of kilowatt-hours?

Mr. MCCONE. I think the recent bids on the two Italian plants I spoke of, the Edison Volta and the SENN, ran $250 to $300 per kilowatt. The British reported to me that the advance generation of the gas-cooled reactors—the improvements on the Calder Hall plant—will run about $300 to $350 a kilowatt. The Calder Hall plants themselves ran $660 a kilowatt.

Representative BATES. What is the cheapest we now have in the United States, how many mills?

Mr. MCCONE. That is a kind of difficult question to deal with because it gets into the period of the generation.

Senator GORE. About 75 mills.

Representative BATES. There are all kinds of figures that I have seen.

Mr. MCCONE. Yes. I would like to go into that question in detail and give you the pro forma on some of the plants, if that were agreeable.

Representative BATES. That is all.

Chairman ANDERSON. Mr. Westland is next. I hope you tell him about the radioactive golf ball; if it gets loose in the rough, you get a geiger counter and find it, not that he cares about it.

Representative WESTLAND. I did not know how it was going to come up, but I was sure in some way golf would turn up in this picture.

Senator GORE. It is an appropriate subject.

Representative WESTLAND. I am here instead of being out on the golf course, Senator.

Senator GORE. I was not making any implications.

Representative WESTLAND. Mr. McCone, I was very much interested in your last three paragraphs, and particularly paragraph 59, because

it seems to me that this should bring to the people of the country more than ever the real battle over the development of atomic energy and radioisotopes, and find out that there is more than just making power or perhaps bombs or airplanes or submarines and that sort of thing.

In your second line you say that the Commission hopes to have powerful leverage. Could you explain what you mean by that? Do you mean the low cost of the development of this, or just what did you have in mind?

Mr. McCone. Yes. We think that the use of the isotope is going to prove of increasing benefit to people throughout the world in areas of biology and medicine, where they will be relieved of pain and disease and assisted in research and medicine. In agriculture, to assist in feeding the hungry; and in industry and other areas. We think the fact that the United States is carrying on an aggressive and progressive program in these very important areas, and doing so at a relatively small cost, is very important and will inure to our benefit. I would say that I think to express this as a powerful leverage may be an incorrect expression of what I mean by that paragraph.

I would like to point out, Mr. Chairman, if I could, some of these contracts. They are very interesting. Let me read two or three of them. Here is a contract with the Armour Research Foundation for the development and production of isotopic sources of secondary X radiation; a contract with Atomic International for feasibility study of industrial radiation purposes of sodium coolants; the Battelle Institute for the development of radioactive tracer control system; with the Chicago Midway Laboratories, the establishment of a broad university isotope program to carry out fundamental radioisotope research; with Curtiss-Wright Co. in connection with the Army for the design and construction and test operation of a multimegacurie cobalt 60 high-intensity food irradiator; the Emerson Radio & Phonograph Co., an analysis of world technology on industrial high-intensity radiation and factors affecting its development; the W. H. Johnson Laboratories, development of a curriculum of study for an industrial radioisotope training course of 6 weeks' duration, the development of experiments and demonstrations suitable for instruction in basic high-intensity radiation technology; with the Massachusetts Institute of Technology, determination of the feasibility of using radioisotope tracer techniques for testing food additives; and so forth.

I just thought that those would be of interest. There are several pages of them here, but I thought that type of work in the field would be of interest to the committee.

Representative Westland. It is very much of interest to me, Mr. McCone, that this can be used for the benefit of humanity rather than for the destruction of humanity, as has been done in many cases.

Mr. McCone. That is the most challenging part of my job.

Representative Westland. I can understand that. I am glad you had an opportunity to put a little of that in the record, and I only wish there were more. You have anticipated my next question, which is, What is being done in the field of medicine and the area of therapy? I see nothing in your statement along those lines. I am sure that there are developments.

Mr. McCone. Perhaps Dr. Libby would address himself to that question.

Chairman ANDERSON. Wouldn't it be fair to add that in the material which you submitted, taken from the semiannual report, which is hard to get to immediately, there is quite a bit of reference to that?

Mr. MCCONE. Yes.

Chairman ANDERSON. I would be very happy to have Dr. Libby comment on the work at Brookhaven and elsewhere. I think Mr. Westland has asked a very good question. We are all interested in it.

Mr. LIBBY. I think on the matter of medical uses of isotopes, if you don't mind, I would ask Dr. Dunham to answer your question. He is a medical doctor.

Representative PRICE. Mr. Chairman, may I state that the committee at times has had separate and special hearings extensively on this subject. I think some very valuable documents have come out of this committee, specifically on the work done in the field of medicine, also in the field of biology. We have had extensive hearings on all these works. I am glad that the gentleman from Washington brought that up, because this is an extensive field in which a great deal of work goes on. It is too bad that a major attention goes to the more dramatic features of the atomic energy program, but certainly the Commission has not been negligent in any way. I know the gentleman did not mean to infer that. That is, in putting all the effort it possibly can into research in the field of medicine and other beneficial areas.

Representative VAN ZANDT. Is it not true that each spring the subcommittee of the Joint Committee which the gentleman chairs spends at least a week or more taking testimony from all concerned in the field of peacetime uses of the atom? The documents that we have produced from year to year are sometimes referred to as the bible of peacetime uses of the atom.

Representative PRICE. I think that is correct.

Chairman ANDERSON. Dr. Dunham, did you wish to make a statement?

Dr. DUNHAM. I will make a very brief statement. I think you are aware that the Brookhaven medical reactor is about completed, and we hope thereby to intensify exploration of the use of pile generated neutrons in the treatment of brain tumors and very likely other types of cancer. Also, studying certain trace elements such as magnesium and manganese, distribution in the human body, we are finding certain things out about some of the degenerative diseases of the nervous system which are so important these days—such things as Wilson's disease and Parkinson's disease, which is a form of shaking palsy. These names may not mean too much to you. These tracer approaches to some of these degenerative diseases look like they are going to lead to very great breakthroughs.

Routinely we are using radioisotopes in the diagnosis and treatment of thyroid conditions and even in certain types of heart disease.

Representative WESTLAND. Isn't it true, Doctor, that thousands of lives have been saved through the uses of atomic energy, let us say, or radioisotopes?

Dr. DUNHAM. I am sure many, many lives have been prolonged, and certainly thousands of lives have been prolonged. How many have actually been saved in the literal sense of the word would be hard to say. I am sure hundreds have.

Representative WESTLAND. I merely conclude my few remarks here, Mr. Chairman, by saying that I wish this phase of the development

of nuclear power, atomic energy, or radioisotopes could get a little more publicity so that the people of the country would know a little more about the beneficial uses, rather than its destructive powers.

Chairman ANDERSON. In paragraph 6, you mention carrying out the reorganization of the Division of Reactor Development. You say no significant change is made in overall manpower. You have 42 persons on the payroll out there now. You plan to reduce this to 37 on June 30. Do you feel that 37 people—since Senator Gore pointed out how much more money the AEC spends than private industry on civilian reactor development, do you feel that 37 people are sufficient to cover that very broad field?

Mr. MCCONE. Dr. Pittman, have you got your organization chart here?

Mr. PITTMAN. No, sir, I don't. The 37 is certainly not the correct figure.

Chairman ANDERSON. What is the correct figure?

Mr. PITTMAN. If you count the military and everything——

Chairman ANDERSON. No, I didn't count the military. I said civilian reactor program is now 42. It is being cut to 37. You say that is not correct. Will you furnish the correct number?

Mr. PITTMAN. 193, I have been informed.

Chairman ANDERSON. For civilian?

Mr. PITTMAN. I don't think that is right.

Chairman ANDERSON. Let us identify the witness who said 193.

Mr. TACKMAN. Arthur Tackman, Director of Personnel. The total number of civilian employees is 193. Your figure is correct for that branch.

Chairman ANDERSON. That is what I thought. Proposed for civilian power reactor development program, 37 people. It is now 42. Does anybody want to dispute that?

Senator GORE. It is about as ambitious a program as it was under Admiral Strauss.

Chairman ANDERSON. Do you think 37 people is sufficient for civilian reactor development in the United States when private companies have far more, and we are spending far more money than all of them together?

Mr. MCCONE. It sounds a little low to me, sir.

Chairman ANDERSON. Don't you think it was a bad direction to turn it downward instead of upward?

Mr. MCCONE. I think it was related to the program of decentralizing as much of this as possible to the division offices, most particularly Chicago, Idaho, and New York, at which they have very substantial staffs; at Chicago they have 293. In Idaho, they have 348. In New York, 288.

Chairman ANDERSON. When you get to Chicago, you don't find a large technical staff there.

Mr. MCCONE. That is correct.

Chairman ANDERSON. You are counting the number of people. They have a very, very small technical staff, do they not?

Mr. MCCONE. Yes; it is an administrative staff.

Chairman ANDERSON. Washington is supposed to provide the technical direction on it. It seems like a rather small staff compared with the responsibility. We asked a while ago about this question of au-

thority that was raised. Could I go to this paragraph 39, and ask if we could be furnished by your attorney the authority for the enriched fuel for foreign reactors? I do that because of the question that Senator Dworshak originally raised. Do you do that under waiver of fuel charges? What authority? This is paragraph 37 on page 12.

Mr. OLSON. I think it is under the authority of section 54 of the general authority to sell at domestic prices and we interpreted that as giving us the authority to sell in terms that provided for interest plus burnup charges. It is our interpretation section 54 gives us the authority for that 10-year deferred payment plan. That is what you have reference to.

Chairman ANDERSON. Yes. I merely wanted our record to have a statement from you to cover the point that Senator Dworshak had originally raised about authority for this.

With reference to this controlled thermonuclear which I mentioned in paragraph 48, Congressman Price I think asked a question. The matter is completely declassified but all documents are not in the open. Can you give any estimate when they might be?

Mr. MCCONE. Yes. Mr. Olson will comment on that. I do not have the latest report. We are making an effort to try to get everything in the open by January 31, but we did not succeed in meeting that deadline.

Mr. OLSON. I believe you are aware that quite a few of these documents were held up for patent review. The Chief of the Patent Division advised me yesterday that he completed that patent review. That has been the biggest delay. That has been completed as of yesterday.

Chairman ANDERSON. Thank you. I have a lot of questions I would like to ask but I think we better get on to civilian power.

MERCHANT SHIP PROPULSION

Mr. MCCONE. Closely related to the civilian power reactor program is the work on nuclear propulsion of merchant ships. The first nuclear-powered merchant ship is the NS *Savannah*, a joint project of the Commission and the Maritime Administration. Its operation, beginning in 1960, will give us firsthand experience with the many new problems we can anticipate in commercial operation of nuclear-powered ships. It will not be a competitive vessel being subject to the economic penalties which attend any pioneer demonstration project.

In addition to the development and construction of the pressurized water nuclear plant for the *Savannah*, the Commission is engaged in the necessary support programs related to its early operation. This work involves crew training, development of health and environmental safety, development of maintenance procedures, design of shore support facilities, and efforts devoted to the establishment of construction standards and operating regulations. In addition, the Commission will give technical support to nuclear aspects of the Maritime administrative program.

Design studies in progress by the Commission for future merchant ship reactors include investigations of boiling water reactor system and a longer range program for development of a gas-cooled reactor, closed-cycle propulsion system. In addition, development in reactors

for central station use will make a direct contribution to propulsion reactors.

That concludes the statement on the merchant ship propulsion.

Chairman ANDERSON. I might say I have been very anxious to have a tanker built. We almost got money a year ago to build a tanker.

Mr. MCCONE. I spent some time before the Merchant Marine and Fisheries Committee this morning. Being an oldtime shipbuilder and operator, we had quite a time.

Representative VAN ZANDT. Is the *Savannah* at the moment the only ship propulsion project we have? Domestic, of course.

Mr. MCCONE. The only commercial; yes. There is a big family of Navy vessels which you are familiar with.

Representative VAN ZANDT. *Savannah* is the only commercial atomic-powered project that we have at the present time?

Mr. MCCONE. That is correct, sir.

Chairman ANDERSON. Where do we go now, Mr. Chairman?

Mr. MCCONE. I would like to go to page 20, paragraph 60, civilian nuclear power program. The balance of the paper will discuss the civilian power program. The forepart of it will be devoted to the general philosophy, let us say, or approach, which is a departure from prior policies of the Commission which I will come to. Then that will be followed by the specifics of the 1960 program.

CIVILIAN NUCLEAR POWER PROGRAM

Now, I would like to present to you the Commission's civilian nuclear power program. The present status of the program is summarized in the excerpts from the 25th semiannual report, pages 16–47.

The program for development of civilian power reactors may be considered as having completed its first phase. It was just 5 years ago that the Commission, with the approval and support of the Joint Committee, launched the first formal civilian nuclear power program. I believe that efforts during the past 5 years have paid off in remarkable progress. I believe we have had a good program, both in terms of technical progress and in terms of participation and cooperation of industry.

There have been waves of optimism and pessimism as the development effort has progressed. There now seems to be a rapidly improving basis for projecting the technology to actual achievement of some of our short-range program objectives. As this basis for projection continues to improve and as there is less uncertainty in our extrapolations of nuclear power technology, there will be less need for pursuing a multiplicity of projects primarily for greater assurance that a specific goal will be achieved.

As the committee knows, the last year or so has been a period of evaluation and reappraisal insofar as our civilian nuclear power program is concerned. Various groups both inside and outside of government have made valuable contributions to this process. In addition to the attention given to this problem by the Commission and its staff, including the Commission's statement before the Joint Committee on June 3, 1958, I would mention particularly your committee's staff report on a "Proposed Expanded Civilian Nuclear Power Program," the comments regarding it from representatives of equipment

manufacturers, the utilities, and nuclear specialists, and the survey on "Status and Prospects of Nuclear Power" conducted by a committee from the electric utility industry and distributed by the Edison Electric Institute. Imaginative programs for achieving economic nuclear power within the next few years also have been put forward by individual manufacturing companies prominent in reactor work.

In October of last year, I called upon an eminent group from the business and scientific communities, constituted as an ad hoc committee on reactor programs and policies, to advise the Commission. A very fine report was submitted by this group last month.

Copies of that report have been given to your committee.

The Commission and its staff have considered these reports and recommendations, as well as other information at its disposal, at great length and with very great care in order to formulate a statement as to what its civilian reactor policies and programs should be. I have such a statement to present to you today. While we acknowledge with gratitude the help we have received from all the groups I have mentioned, I would emphasize that this statement is an expression of the Commission's own convictions.

PROPOSED NUCLEAR POWER PROGRAM

A. Objectives

The objectives of the national civilian nuclear power program are to—

(1) Reduce the cost of nuclear power to levels competitive with power from fossil fuels in high energy cost areas of this country within 10 years.

(2) Assist friendly nations now having high energy costs to achieve competitive levels in about 5 years. This assistance is to be extended mainly through clearly defined programs of cooperation.

(3) Support a continuing long-range program to further reduce the cost of nuclear power in order to increase the economic benefits and extend these benefits to wider areas.

(4) Maintain the U.S. position of leadership in the technology of nuclear power for civilian use.

(5) Develop breeder type reactors to make full use of the nuclear energy latent in both uranium and thorium, recognizing that U–235 alone may not be sufficiently plentiful to meet our needs over the long range.

B. Responsibility

It shall be the responsibility of the Atomic Energy Commission to provide positive and vigorous leadership in the national efforts to achieve these goals. In exercising this leadership, the Commission will make full use of the technical talents and capabilities of its own laboratories, and of all segments of industry which can make substantive contributions.

In assuming leadership in this, the Atomic Energy Commission recognizes that various public and private utility and industrial groups will carry out ever-increasing developmental, construction, and operational activities, and the AEC will give full consideration to such work in the development of the program to meet the overall objectives.

In general, the technical work which must be carried out to trans-

late an idea into a plant producing commercially competitive power may be divided into three phases.

Phase I—Research and development: During this phase of the work the technical feasibility of a concept is established through activities such as laboratory work, technical analyses, critical experiments, test radiation, reactor experiments, experimental reactors, design studies, and evaluation. Much of the work done during this phase is general research and development which is applicable to many different concepts but, as this research work progresses toward the construction of experimental reactors, it becomes more specific and less general.

The Commission will be responsible for assuring that all necessary work in this phase is carried out in a manner and on a schedule that is consistent with meeting the objectives of the program. In discharging this responsibility, the Commission will give full consideration to industrial programs in this field.

Phase II—Prototype construction: When the efforts under phase I have shown technical feasibility, and when it is clear that a given concept or modification thereof offers real promise of accomplishing one or more of the objectives of the program more effectively, more rapidly, or at a lower cost than seems to be possible by other means, it may be necessary or desirable to build a prototype reactor. These prototypes will have the dual purpose of producing power and important and essential technical information. They will provide data on plant-construction costs, and statistically significant information on efficiency, performance characteristics, and other operating factors in a manner which will permit reliable projection toward central station powerplants. The size of these prototype reactors will be dependent upon individual circumstances. They would be of a size consistent with the objective of developing information at minimum cost and in the shortest possible time.

Emphasis on prototype reactors should accelerate the rate at which technical data can be developed and thus should accelerate progress in nuclear power technology. It is important, however, that prototype reactor projects be carried out in a manner which brings to bear the special talents of various segments of industry, including utility operating practices.

In order to assure meeting program objectives, the Commission must have full responsibility for this phase of the program. It will determine what reactor concepts meet the criteria for construction, will select the approximate size and conceptual design best suited to accomplishing the basic objectives, will determine schedules for construction and operation, and will assure that the unit will be operated in a manner which will be most useful to the program.

Representative HOLIFIELD. Mr. Chairman, before we go to the next point, which takes up phase II, I would like to ask this question:

In looking over this statement up to date from the proposed nuclear power program on page 22, you are stating a general set of principles by which to proceed. Would you not agree with me that even though this statement of principles is made, and even though it seems to be a very reasonable statement of principles, that the real test of it is what kind of a program you apply the principles to?

Mr. MCCONE. Yes, sir; I agree.

Representative HOLIFIELD. If you have a very weak program or a very small program, you can apply these principles to it just the same as you could an aggressive, dynamic program that would be constructive and getting something done. If you are going to keep cutting down the program and applying these principles to it, the principles themselves make very little difference. But if you have a real program to apply these principles to, then you have something that is really valuable in the progress of the technology. So in evaluating the principles which you are enunciating here we will eventually have to apply this to the program. If you apply it to the program and you find out you have very little program, the principles are not very valid.

For instance, you refer to pages of this book in the semiannual report from 16 to 47. When you take into consideration recent developments, such as your cancellation of the Chugach project and your virtual cancellation or postponement of the Hallam project, then you have to take the principles out because the principles do not apply to the advancement of the art in the fields concerned.

Mr. MCCONE. I think the program I outline to support these principles you will find to be quite constructive.

Representative HOLIFIELD. I know we will get to that. In the beginning you said you thought that progress has been made in a remarkable way. As far as your demonstration program is concerned, that is not true, because private industry just has not come forward and done the job that it was expected to do. Even private industry admits that. Your ad hoc committee admits it. The JCAE staff report admits it. You may point to it as making remarkable progress in the last 5 years, but that certainly is a matter of individual evaluation, and some of us don't feel in that field there has been very much progress. I think that is pretty well the opinion of industry because industry itself has come to us in these seminars and said they are disappointed with the program and they are disillusioned with the progress that has been made since 1954.

So unless you come forward with an aggressive program on all points that need to be developed, and apply these principles to that program, the enunciation of the principles is not going to get us very far.

Mr. MCCONE. I think since there has been some considerable discussion as to just what the role of the Atomic Energy Commission is it might be well to establish the principles and then I will lay out the program, and I have it here, sir.

Representative HOLIFIELD. I am glad to see you lay out the principles. I am not antagonistic to the word "principles" at all. I am glad to see that the Commission is accepting some definite, specific responsibility in this field. I think if they accepted these same responsibilities during the past 5 years we would have been much further along.

Mr. MCCONE. I can't comment on the last 5 years. I can look to the future, sir.

Representative HOLIFIELD. I realize that.

Senator GORE. The chairman has already commented on the past 5 years. He said in his statement that we have had a good program. I

think you have had a miserable program. It has failed miserably, else you might not be Chairman of the Commission.

I suggest, Mr. Chairman, that these general rules—I will say to my friend from California—or general principles, are fine. We may come to the Golden Rule pretty soon.

Representative HOLIFIELD. We will be for that, too, will we not?

Senator GORE. Yes, indeed. But I also want to see some application.

Mr. MCCONE. Continuing with the statement:

In phase II, as in the research and development phase, the Commission will take into account the efforts of private industry.

In recognition of the importance of industrial participation in this phase of the program, the Commission will consider giving financial assistance toward the capital cost of prototype reactors to utilities willing to construct and operate such reactors under conditions which assure that the objectives of the Commission are being met.

I would like to emphasize in referring to utilities, and all other references in this paper I refer to both the public and private power groups or organizations.

To implement phase II of the program, the Commission would—

(1) Determine that a reactor concept meets the criteria for construction of a prototype. In making this determination, the Commission would obtain the advice of various segments of industry and the scientific community through advisory groups.

(2) Select the size reactor best suited to accomplish the desired objectives.

(3) Develop general designs and specifications in sufficient detail to give guidance to proposers and to insure that proposals will be responsible to the Commission's needs with respect to such things as the type and size of the reactor, and also its cost.

(4) Announce that a prototype reactor of the type specified should be built to advance the overall program, and invite proposals from the utility industry for its construction. The invitation would be directed to both privately and publicly owned utilities. In addition to all other necessary facts, the invitation would establish the time for submission of the proposal; the technical specifications of the plant, the minimum obligations which the utility must assume with regard to design construction, and operation; the types of financial assistance considered, including assistance on capital costs of the plant; and other facts pertinent to the proposal. The invitation would state that if satisfactory proposals were not received, the Commission, within the limits of authority and funds, would undertake construction of the reactor at a Commission site.

In addition to projects resulting from specific invitations of the Commission in accordance with procedures outlined above, we believe the utility industry will wish to make unsolicited proposals which would lead to the construction of nuclear powerplants. The Commission may determine that the projects proposed also would make significant contributions toward the achievement of the Commission's goals and objectives. In the event of such a determination and within existing authority and funds, the Commission will provide assistance in the form of research and development and waiver of use charges for such reactors.

Phase III—Construction of commercial units: When the results of phases I and II of the program indicate that it is possible to construct nuclear power stations which will produce electricity competitively with fossil fuel plants in certain areas of the country, the forces created by growth of demand for electric power normally can be expected to stimulate the construction of commercial nuclear powerplants on their strict economic merits. In this phase of the program, it is expected that industry will assume the primary responsibility for the program.

Representative HOLIFIELD. Could I stop you there and ask a question, Mr. Chairman.

I notice in paragraph 4 on page 26 you set up a formula which has within it the including assistance on capital costs of the plant. This would only apply to the power demonstration program, would it not?

Mr. MCCONE. That is correct.

Representative HOLIFIELD. In other words, this would not apply to any kind of experimental reactor program?

Mr. MCCONE. Experimental reactors we will build on our own sites.

Representative HOLIFIELD. In other words, any reactor that was built with all Government funds would be on our own site.

Mr. MCCONE. Yes, sir.

Representative HOLIFIELD. It would not be built on any other site?

Mr. MCCONE. No, sir.

Representative HOLIFIELD. So therefore in your setup here you have precluded any opening up of any so-called second round to build the reactors on the Shippingport formula, on Consumers of Nebraska formula, or that type of building of reactors would not be included in your program?

Mr. MCCONE. That is correct.

Representative HOLIFIELD. That answers my question.

GENERAL PROGRAM TO MEET OBJECTIVES

Mr. MCCONE. The Commission considers the objectives stated for the national civilian nuclear power program to be attainable and important to this country. The Commission believes that the general framework just described for carrying out a program to meet these objectives is consistent with their importance and compatible with American industrial patterns. The Commission takes very seriously its responsibility to provide positive and vigorous leadership in the national efforts to achieve these objectives.

In order to meet these stated objectives, the Commission must carry out—

(1) A program of research on the fundamental properties of materials vitally important to reactors;

(2) General research and development programs, including where necessary, loop experiments, critical assemblies, and reactor experiments, on the several reactor concepts which show technical promise;

(3) More specific research and development programs, including experimental and prototype reactors which, because they

appear to have either (*a*) simple, safe, and reliable design; (*b*) high specific power or power density; (*c*) low-cost fuel cycle; (*d*) high thermal efficiency; (*e*) favorable neutron economy; or (*f*) other special advantages offering reasonable probabilities of making important contributions to the production of low-cost power. It will be the policy to provide in this way in the public domain the basic knowledge and information necessary as a foundation to nuclear power development.

This knowledge and information has value completely separate from its relationship to nuclear power development. New materials, instruments, and instrumentation systems are being developed which are useful in a variety of applications.

Achievement of program objectives will require reduction in both capital costs and fuel cycle costs. Capital cost reduction requires special attention to simplification of design without loss of safety or reliability. This component of cost also will be aided by improvements in power density and specific power, and by increased thermal efficiency.

One of the most important factors in the production of low-cost nuclear power and one that has a greater and greater relative impact as the capital costs of reactors is lowered, is the cost of producing, fabricating, and shipping fuel and of handling and processing spent fuel. For this reason, the Commission will enlarge upon its previous effort and place major emphasis on an intensive program aimed at solving the problems of the nuclear fuel cycle. This program will obviously give adequate consideration to the needs of the specific projects under construction, but it will place major emphasis on such things as materials research, general fabricating techniques, standardization of fuel, and the possibility of incidental income from by-product use of radioactive isotopes from the spent fuel.

The Commission is now offering to provide certain services to the nuclear fuel cycle, such as processing of irradiated fuel. We are doing this as an interim measure and intend to do so only to the extent necessary in the absence of such services from industry under reasonable terms. It is to the interest of both the Commission and the utilities that industry should provide these services.

The objectives of the civilian power reactor development program are stated and the technical program is oriented primarily toward the generation of electricity. It is recognized, however, that potential civilian uses of nuclear energy include providing heat and/or radiation for industrial processes and heat to warm buildings.

Industrial processes of various kinds in the United States actually consume considerably more heat energy than is used for the generation of electricity. Required temperatures cover a wide range from around 400° F. for pulp and papermills, for example, to 2,000 or 3,000 degrees for some chemical or metallurgical processes. Low temperature heat for industrial processes or space heating can be produced by reactors currently under development. The technical feasibility for using reactors for high temperature process heat has yet to be determined.

While the technical feasibility of providing space heat from reactors is clear, this application may not have great civilian significance in the United States at this time because of limited facilities for distribution of central station heat.

I am now prepared, sir, to go into a specific program or to answer questions.

Chairman ANDERSON. I think perhaps it would be better to answer questions. Senator Gore?

Senator GORE. Mr. Chairman, you have now finished your general statement on the civilian nuclear power program. I noticed that you say on page 26, that invitation will state that if satisfactory proposals are not received, the Commission, within the limits of authority and funds, would undertake construction of the reactor at a Commission site.

I have been severely disappointed at the absence of an adequate specific program in the Commission's presentation. I would like to read a few excerpts from your predecessor's statement before this committee describing the previous program which you described as good and then ask you if you will, please, to show how the program of the Commission today differs from the staements we have had before.

To begin with the former Chairman of the Commission said on January 31, 1955:

> The Commission recognizes that the greatest advances in reactor technology will come from the actual construction and operation of large-scale reactors on a commercial basis. There is no effective substitute for such practical experience.

I find myself in agreement with that statement. Do you?

Mr. MCCONE. No, sir; I do not agree with that statement. I do not think that the most rapid approach to economical nuclear power results from the building of large, central stations at this time, which obviously must be of limited efficiency or questionable efficiency, and take a considerable time to build.

I think that we can advance the technology much better and much cheaper and much faster by building modest size prototype plants of the type we propose. In this regard, I disagree with that statement, sir.

Senator GORE. You, then, think that we should not build large-scale commercial powerplants?

Mr. MCCONE. I feel that the technology that has been developed through the past years must be built into plants of a prototype nature as rapidly as possible if we are to make maximum progress in this field. I think that if we attempt to build that technology into large plants, that a delay will result.

Senator GORE. Then, you do emphatically disagree with the statement which I have read?

Mr. MCCONE. Yes, I do.

Senator GORE. In appearing before this committee in 1956, the former Chairman had this to say:

> In the event that a reactor design is offered which private industry does not move forward to undertake, I personally would recommend to the Commission, and I believe the Commission would under those circumstances, undertake to construct it at Government expense.

How does the statement you have presented here today differ from that?

Mr. MCCONE. I don't think it does differ, because I have said in my statement, in the paragraph you referred to, that if industry does not submit an acceptable proposal then if this plant is considered

desirable we should build it on our own site for demonstration purposes and consume the electricity produced in our own operations.

Senator GORE. I could not detect any difference.

Mr. MCCONE. I don't think there is any difference.

Senator GORE. That is what I thought.

Chairman ANDERSON. Senator Gore, would you mind giving a page reference to that?

Senator GORE. That reference I read is on page 36 of the hearings on the so-called Gore-Holifield bill, on May 23, 1956.

Chairman ANDERSON. Thank you.

Senator GORE. Again, the former Chairman said:

> We are prepared to exercise that authority and to request appropriations for such plants whenever it appears to us as a true test for this effort that we have developed a reactor concept sufficiently to make it timely for the construction of a prototype, and when after appropriate public invitations for proposals for joint AEC-industry projects it appears that industry in a cooperative enterprise is not prepared to undertake such construction.

It says the same thing as in the other statement. I will be glad to submit it to you to read it.

Mr. MCCONE. I am not familiar with the statement but your reading of it is quite satisfactory to me, Senator.

Senator GORE. How does that differ?

Mr. MCCONE. What differs here, however, is that I think Admiral Strauss in all of his programs was contemplating a plan under which a reactor concept would be called for and then if industry did not provide all of the money and go forward with the building of it, excepting perhaps research and development assistance, then he anticipated that the Government would build it.

We have approached a little differently, sir. We have injected into the formula the idea of a capital grant.

Senator GORE. You are going to help them pay for it?

Mr. MCCONE. Yes, sir.

Senator GORE. That injection is questionable.

Mr. MCCONE. It might be. This is our proposal, sir.

Senator GORE. Mr. Chairman, I find you a very pleasing person with whom to have social contact or other contacts. You said two things here which are not entirely pleasing. The manner in which you say them is pleasing, but their substance is very disappointing. You have said (1) that we have had a good program for the past 5 years. You have said (2) that your present program is the same except that you propose to give to private industry a part of the cost of constructing plants.

Mr. MCCONE. May I just point out that I am not confining to private industry because I would feel, from my discussions with any number of public groups, that they would like to join in such an undertaking.

I am speaking of the utility industry, private and public.

Senator GORE. I appreciate your correction. I did not purposely intend to draw a line between public or private power groups, and I appreciate your correction.

Representative HOLIFIELD. If the gentleman would yield there, I would like the record to stand that there is not a possibility for the public power people to participate in this type of a program because

it is well known that public power people have no reserves in which they could participate in a capital investment in a plant.

Senator GORE. The Atomic Energy Commission is going to give it to them.

Representative HOLIFIELD. While it is an invitation, it is like asking you to come over to my house to dinner when you are sick in bed and you can't leave your own home. The invitation is there but the capacity to accept the invitation is lacking.

Senator GORE. That is apparent.

Representative HOSMER. Would the gentlemen yield?

Senator GORE. Yes; I yield.

Representative HOSMER. The public power groups which you are talking about are such things as municipal utilities and so on, are they not?

Mr. MCCONE. That is right.

Representative HOSMER. They have capital to build their own plants, do they not?

Mr. MCCONE. That is right.

Representative HOSMER. Under this concept of capital assistance, would it be something in the nature of the cost difference between a conventional plant and the higher nuclear plant?

Mr. MCCONE. That is correct.

Representative HOSMER. It involves only prototype plants and not large-scale plants?

Mr. MCCONE. That is correct.

Representative HOSMER. In the nature of an experimental plant?

Mr. MCCONE. No; it would be a larger plant than an experimental plant.

Representative HOSMER. Say 50,000?

Mr. MCCONE. 50,000, 75,000 kilowatts.

Representative HOSMER. Not really an efficient plant.

Mr. MCCONE. No; but it would be a plant large enough to demonstrate on a commercial scale the economic feasibility of what is under test.

Representative HOSMER. And its purpose would be to test out machinery and the economics?

Mr. MCCONE. Yes; these various technical points I have enumerated.

Representative HOSMER. Whether it was done in cooperation with a private utility or a public utility?

Mr. MCCONE. That is correct.

Representative HOSMER. It would undoubtedly, I take it, be in those cases where the added cost factor of the nuclear powerplant would deter either the public or the private utility from installing it themselves?

Mr. MCCONE. What is going to happen is this: The public utility groups, under their charters, can invest in plants and do have funds to invest in plants that approach the cost of conventional plants. Some of them tell me that they can go past that under their charter which permits research and development which might lead to improvements in their system in the future.

They cannot, the public group, go past that. Their charters do not permit them to do so. For that reason in these programs, you

have found them unable to participate except through the second-round device. On the other hand, the private industry groups have formed organizations and have picked up the difference between the cost of the conventional plant and the cost of the nuclear plant and they have done it in various ways which have been possible because of their capital structure and their tax situation and so forth.

Representative HOSMER. I have just one more question, if I may.

The net effect of this whole thing is that without such capital contribution you may not have certain prototypes built that should be built, unless the Federal Government pays the whole price.

Mr. MCCONE. That is correct.

Representative HOSMER. Thank you.

Senator GORE. As I said earlier, I had not intended to draw a line of distinction between public or private power groups. It has always been my view that this argument is not particularly related here, nor is the question of ability or inability of certain groups to participate in a program or to accept the invitation, as Congressman Holifield refers to it. I am sorry that I had inadvertently omitted the word "public" as well as private power groups.

You have described the program for the past 5 years as good, and you have stated that the program you now suggest is the same except you propose to make it a little sweeter by capital grants. The previous program proposed to sweeten it up by the buy-back of the fuel elements.

Will you tell us just how many reactors have been constructed under the program for the past 5 years?

Mr. MCCONE. Yes. I have a chart here which shows the entire program. It might be the best way to answer this question.

Chairman ANDERSON. May I announce that we are going to quit at 5 o'clock. I assume that the Chairman has some work to do, and I know that the members of the Joint Committee do.

Representative VAN ZANDT. Mr. Chairman, would this not be a good point at which to recess and come back tomorrow before we get to this chart?

Senator GORE. It would suit me.

Chairman ANDERSON. If we could do so, that might be well. I would hate to see us start with the chart and not complete it. I know I have not been in my office since 9:30 this morning.

We will stand in recess until 2 o'clock tomorrow afternoon.

Mr. Chairman, you can come back at that time.

Mr. MCCONE. I will be here; yes, sir.

(The letter from Dr. Walter H. Zinn referred to on p. 15 follows:)

GENERAL NUCLEAR ENGINEERING CORP.,
Dunedin, Fla., October 21, 1958.

JOINT COMMITTEE ON ATOMIC ENERGY,
U.S. Senate Post Office,
Washington, D.C.

GENTLEMEN: You have asked me to record my overall impression of the U.S.S.R. presentation in reactor technology at the Second International Conference on the Peaceful Uses of Atomic Energy.

Since a great many papers were presented by the U.S.S.R., it is not possible in a short review to refer to these specifically. As a matter of fact, I have not had time to read many of these papers and, at the Conference, it was physically impossible to be present when many of them were given. Some of the impressions I report here, however, were obtained in talking to members of the staff of General Nuclear Engineering Corp., who did hear the papers.

TECHNICAL PROGRESS

1. Perhaps the strongest impression which I have acquired is the fact that technical progress is rapid, and that it is closely coordinated with a program of building intermediate and large-scale power reactors. The fact that there are now under construction fairly large reactors involving technology which the U.S.S.R. obviously did not have in hand in 1955 indicates that the research and development supporting effort, as well as the program of reactor construction, must be large and vigorous. As examples of this statement, I would offer the following:

2. In 1955, the U.S.S.R. obviously did not have a program involving boiling water reactors; in fact, considerable skepticism was expressed concerning the feasibility of removing steam from practical size reactors. Nevertheless, there is now under construction a 50 eMW boiling water powerplant. The technicians associated with the boiling water reactor seem to have a good grasp of the problem involved and are constructing the boiling water powerplant in such a way that a fairly large range of variations can be explored. Therefore, it is an experimental type of machine, but is a large experiment. As a variable, it was noted that the pressure vessel is designed for 2,000 p.s.i. This is double the pressure of any existing U.S.A. boiling water reactor and gives an opportunity for exploring parameters over a large pressure range.

3. Another example of the rapid development of technology is the fact that in 1955 the U.S.S.R. quite obviously did not have zirconium or zirconium alloy of a kind suitable for reactor construction. At this year's conference, they exhibited a fuel element which used zirconium as structural material. Two reactors shown, namely the boiling water reactor and the pressurized water reactor, will have zirconium alloy fuel elements. Also, metallurgical papers were given in which new zirconium alloys were revealed and their properties superior to the alloys so far developed in this country. The fact that the U.S.S.R. has been able to develop zirconium technology in itself is not impressive, since the U.S.A. has continuously furnished, in the open literature, detailed information about the materials and, to some extent, the methods of preparation. What is impressive is the fact that in 3 years the appropriate technology has been established.

4. The second overall comment I could make on the U.S.S.R. program is the fact that it is comprehensive, as is that of the U.S.A. Practically all of the principal types of reactors under exploration in the U.S.A. also are being explored by the U.S.S.R. It seems to be a matter of definite policy to explore all possible avenues for power reactors and to follow promising avenues to at least the stage of an experimental nuclear powerplant—this plant would quite likely have a size of about 50 eMW. Where there is less doubt about the technical feasibility, it also seems to be a matter of policy to follow up the large-scale experiment with a major power station having a rating of from 250 to 600 eMW. Apparently no decision has been made at the present time as to the type of powerplant which is thought to have the best chance of ultimately being the best. As in the United States, a variety of thermal neutron reactors are being constructed. All of these have the common difficulty that they can make use of only a small fraction of the uranium; therefore the U.S.S.R. is also exploring reactors in which breeding might be possible. The principal effort in this direction seems to be the fast reactor. Here, also, rapid scaleup is in evidence. Three years ago, apparently, the U.S.S.R. had operated only zero power or critical assembly type of fast reactors. They now have in operation a 5,000 KW thermal fast reactor whose design in some ways resembles the one placed in operation in the U.S.A. in 1951 (EBR–I) but uses plutonium as fuel. Plans are being made by the U.S.S.R., however, to build a 50 eMW and a 250 eMW fast power reactor. The former is somewhat smaller and the latter larger than the Enrico Fermi nuclear powerplant (100 eMW) under development by the Power Reactor Development Co. The point, here again, is not that their fast reactor technology has caught up to or exceeded that of the United States, but rather than in a few years they have arrived at the stage of quite ambitious and large-scale projects.

5. The area in which the U.S.S.R. program differs most from that of the United States is in their exploitation of the graphite-moderated, pressure-tube type of reactor. Two versions of this reactor were brought to our attention during the Geneva Conference. One is an improvement and an extrapolation of the first power station which has been in operation at Obninsk since 1954. The second was the so-called Siberian reactor, which came as a surprise announcement

at the Conference. Several paragraphs describing these projects, as they appear to me, may be helpful.

6. The graphite-moderated, stainless-steel-clad fuel-element reactor is being used in a large-size power station. The power station has a rating of about 400 eMW, using four reactors. Two points with respect to this type of reactor are of real significance: First, the reactors produce steam which is superheated in the reactor, and second, the reactor system has been engineered to operate on a surprisingly low enrichment, namely about 1.3 percent. The superheating reactor boils water in some tubes, generates steam in a heat exchanger with the steam-water mixture, and superheats the secondary steam in other tubes in the reactor. The superheated steam is then sent directly to the turbine. In this use of steam directly from the reactor to the turbine, the Russian reactor takes advantage of what was developed in connection with the U.S.A. boiling water reactors. The reason that the U.S.S.R. can go from a small 5,000 KW plant in one step to a large reactor is that the pressure-tube types of construction permits testing a single pressure tube in the prototype reactor. Once this test has been carried out successfully, the large-scale reactor does not introduce enormously different problems. It is clear that the first reactor at Obninsk has been used for a vigorous program of testing of such channels. These tests were fully reported upon and indicate that the nuclear superheat idea works well. It yields steam comparable to what is used in modern steam plants, namely steam, at the turbine inlet, of temperature of 930° F. and pressure of 1,320 p.s.i.a. A comparable step has not so far been accomplished in the U.S.A. water reactors, although proposals to do so have been placed before the AEC.

7. The Siberian reactor also is graphite moderated. The pressure tubes, however, are not made of stainless steel but of an aluminum-silicon alloy. The fuel is natural uranium in metallic form. The temperature of the water issuing from the channels in the reactor is limited by corrosion of the aluminum-silicon alloy which is used both for the jackets of the elements and for the pressure-containing tube. The reactor is relatively large, having a probable thermal output of approximately 700 MW, if it can be assumed that the 100 MW electrical output is representative of all of the heat produced by the reactor. The design of the reactor is similar to what is the customary Russian design. The fuel tubes enter the graphite matrix vertically. There is an additional novel feature in that the reactor is suspended over the fuel storage cooling pond; discharge of the fuel, therefore, can be directly into the pond. The steam conditions obtained from this reactor are very modest (365° F. at ~ 163 p.s.i.) which requires turbines very large in physical size. Even so, it takes three turbines for the generation of 100 MW. It is doubtful that this reactor has much interest as a power machine alone. As a plutonium producer with some power recovery, it may well be attractive if it is located in an area where the power has exceptional value. It would be a good guess that this exceptional value has to do with other atomic energy activities.

8. The U.S.S.R. placed a great deal of emphasis on the construction of the atomic-powered icebreaker. It is not surprising to find that the icebreaker reactors are pressurized water. It was a little surprising to note that three reactors are used and that these are housed together in a single shield. The reason given for using the three reactors was that two would be required for the approximately 44,000 HP needed for the ship and that the third was an installed spare. No reason was given why it would not have been as good or better to have used only two slightly larger reactors. There was nothing remarkable in the technology of the icebreaker reactors of particular note, with the exception of the design pressure of 3,000 p.s.i. which is very high. It would appear obvious, however, that the effort to install these reactors in the ship would not have been undertaken if there had not been previous experience with a model of the reactor.

9. The technology of building pressure vessels seems to be quite advanced in the U.S.S.R. Apparently large sizes and considerable thicknesses can be fabricated; for instance, the Soviet-designed Czech 150 eMW D_2O-moderated, gas-cooled reactor operates at a pressure of ~900 p.s.i. and uses a pressure vessel having a diameter of 14 feet and wall thickness of about 5.5 inches. In a moving picture, the U.S.S.R. showed that it was fabricating pressure-vessel heads by a die-forming operation using a large hydraulic press. This is an advanced technique and may have certain advantages for quickly and cheaply making pressure vessels.

10. In the area of research reactors, it was noted that the U.S.S.R. has carried out a program of modernizing their reactors, which generally means that the power and neutron flux were increased. Also under design and construction are some new reactors having high neutron flux. Some ingenious ideas concerning pulsed neutron reactors were discussed, and apparently some construction along these lines is underway. It is interesting to note that this also duplicates part of the program which is underway in the United States.

11. The scientists of the U.S.S.R. stated explicitly that no decision has been made as to what kind of reactor is likely to produce nuclear power at the least cost. In answer to a question as to what they would guess might be the best one at some date in the future, there seemed to be some opinion that the graphite-moderated, superheating reactor had a good chance of being the best. Naturally, it would be surprising if all the Russian technologists agreed with this point of view, and it also should be realized that that reactor is more completely Russian than any other. The next 2 to 3 years, if the U.S.S.R. construction program actually follows the schedule given, should produce large-scale experience with all of the important power reactor concepts, with perhaps the exception of the organic-moderated and the homogeneous reactors. Although the U.S.S.R. is doing work on these two lines and a 35 tMW boiling homogeneous reactor is under construction, they apparently have not yet established large-scale power reactors of these types as part of the program.

12. Of interest in a general sense was the construction of a 2,000 eKW pressurized-water power reactor which is to be "mobile." Presumably "mobile" has the same meaning as the U.S.A. package reactors for remote installation.

Yours truly,

W. H. ZINN, *President.*

(Whereupon, at 4:55 p.m., Tuesday, February 17, 1959, the hearing was recessed to be reconvened at 2 p.m., on Wednesday, February 18, 1959.)

DEVELOPMENT, GROWTH, AND STATE OF THE ATOMIC ENERGY INDUSTRY

WEDNESDAY, FEBRUARY 18, 1959

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C.

The committee met, pursuant to recess, at 2 p.m., in room P–63, the Capitol, Senator Clinton P. Anderson (vice chairman of the Joint Committee) presiding.

Present: Senators Anderson, Pastore, Gore, Hickenlooper, Dworshak, Aiken, and Bennett; Representatives Holifield, Price, Van Zandt, Aspinall, Hosmer, Bates, and Westland.

Also present: James T. Ramey, executive director; John T. Conway, assistant staff director; David R. Toll, staff counsel; George F. Murphy, Jr., professional staff member; Edward J. Bauser, technical adviser, Joint Committee on Atomic Energy.

Chairman ANDERSON. The committee will be in order.

Mr. Chairman, as I understand it, you desire now to read the summary of your supplementary statement and then perhaps return to the point on policy we were discussing the other day. That is completely satisfactory. I do want to say that since the supplementary statement is long and some of the members have not had a chance to go through it, that I would hope we might reserve the right to have you appear again at a subsequent date—not right away—after we have had a chance to go through it. It may be that we will finish all the questions we have today, and I would hope we would, but if we didn't I would not want the members who have not had a chance to go through the statement to feel foreclosed.

Mr. MCCONE. I am available, of course, any time. The supplementary statement is rather long. I have written a brief summary at the conclusion of it. I think probably since it deals with the problems in some considerable detail it might be worth while to read it.

Chairman ANDERSON. I do, too. I do not want you to go through it too rapidly. I do want you to read it.

May I say with reference to Mr. Rockwell and Mr. Weaver, who were scheduled to be on at 4 and 4:30 this afternoon, we may not reach you. In case we do not reach you, if there is no objection on the part of the committee we will schedule you for 11 o'clock tomorrow morning, if that is satisfactory.

Would there be objection on the part of the committee to schedule a meeting for 11 o'clock tomorrow morning if we cannot get to them? In case we do not get to Mr. Weaver and Mr. Rockwell and the other questioning, we will have that part of it tomorrow morning at 11 o'clock.

Mr. Chairman, you may proceed.

STATEMENT OF JOHN A. McCONE, CHAIRMAN, ACCOMPANIED BY WILLARD F. LIBBY, COMMISSIONER; HAROLD S. VANCE, COMMISSIONER; JOHN S. GRAHAM, COMMISSIONER; JOHN F. FLOBERG, COMMISSIONER; A. R. LUEDECKE, GENERAL MANAGER; PAUL F. FOSTER, DEPUTY GENERAL MANAGER; L. K. OLSON, GENERAL COUNSEL; F. K. PITTMAN, DIRECTOR, DIVISION OF REACTOR DEVELOPMENT; AND DON S. BURROWS, CONTROLLER, ATOMIC ENERGY COMMISSION

Mr. McCONE. Mr. Chairman, I would now like to present our detailed power program for the forthcoming year. It is covered by a written statement, entitled "Supplemental testimony of Atomic Energy Commission," dated February 17. The first four pages are general and they may be summarized as follows:

The following paragraphs summarize the specific program which has been developed with the foregoing program objectives and implementing philosophy in mind—those are the program objectives and philosophy I was discussing yesterday. With this program we expect to achieve both short-term and long-term reductions in both large and small plants. The reactor concepts in the program divide themselves into four categories which differ as to the time that they can be expected to produce low-cost power. First are the water-cooled reactors, organic-cooled reactors and gas-cooled reactors. Second are the heavy water and the liquid metal cooled reactors. Third are the breeder reactors, and fourth are the fluid fuel reactors.

Our program places increased emphasis in the immediate future on the first category of plants in an effort to achieve low-cost nuclear power at the earliest possible date. Later emphasis will be shifted to the most promising concept in the other categories.

Turning now to paragraph 13 on page 5—I beg your pardon, to the bottom of page 4, "Water-cooled reactors."

Chairman ANDERSON. Paragraph 10 at the bottom of page 4.

Mr. McCONE. Yes, sir; "Water-cooled reactors."

Heterogeneous reactors which are moderated and cooled with light water are particularly suitable for meeting short-range program objectives and have promise for meeting the long-range program objectives. They are suitable for small plants as well as large plants, although pressure vessel size limitations may become important in very large sizes.

The major portion of power reactor technology developed and demonstrated to date in the United States is based on water reactor systems. Feasibility and reliability have been demonstrated by those reactors now built and in operation. All the water reactors now in operation produce saturated steam. The use of saturated steam requires larger and more expensive equipment in the nonnuclear portion of the plant than is now used in superheated steam, fossil-fueled plants. The large-volume flow, erosion and corrosion problems introduced by high moisture content, and lack of production volume, all contribute to the relatively high cost of the nonuclear portion of a saturated steam nuclear plant.

Although technology in water reactors is further advanced than in other reactor concepts, the lack of statistical information on fuel ele-

ment behavior and plant performance makes economic potential uncertain. For these reasons it is necessary at least for the present to continue extensive effort on at least two other reactor types to meet the objective of competitive power at the earliest date and to provide competitive incentives as well as to provide insurance in case some of the expected developments in the water reactor concept do not materialize.

A. PRESSURIZED WATER REACTORS

The pressurized water reactors have reached a more advanced state of development than any other reactor type due primarily to the extensive research and development work carried out in the development of nuclear powered propulsion plans for the Navy. The research and development work plus the operating experience in propulsion plants and land-based prototypes has culminated in the design and construction of the Shippingport plant. Based on this technology the Yankee Atomic Electric Co. and the Consolidated Edison Co. are in advanced stages of construction of central station plants utilizing pressurized water reactors.

The pressurized-water reactor differs from the boiling-water reactor in that bulk boiling and steam generation in the core is prevented by the pressure maintained in the system. Thus, a pressurized-water reactor has a primary loop which transmits reactor heat across a heat exchanger to the nonradioactive secondary side of the system where the saturated steam is formed for driving the turbine. Demonstrated stability and load following characteristics of large reactors and absence of radioactivity in the steam system are important assets of pressurized water reactors.

During fiscal year 1960 much new information on pressurized-water reactors will become available from reactors of this type now operating or under construction. The principal area for improvement in these reactor systems appears to be the development of improved, lower cost fuel elements. It appears that improvements now being considered can be tested by installation of new cores or other experimental operations of plants already planned. Thus, it is considered unnecessary to initiate construction of a new prototype pressurized-water-reactor powerplant in fiscal year 1960.

Specific activities to be carried out during fiscal year 1960 are summarized in the following paragraphs.

Pressurized water reactor (PWR—Shippingport)

The pressurized water reactor at Shippingport, Pa., produces 60,000 KWE, operating at 2,000 p.s.i. in the primary system producing saturated steam at 560 p.s.i.a. in the secondary system. Operation started in December 1957. Operation, research, development, and fabrication of improved cores will continue during fiscal year 1960. Early in fiscal year 1960, the enriched portion (seed) of the initial core will be replaced. At the same time one or more natural uranium oxide (fertile blanket) fuel bundles will be removed from the reactor for study of plutonium buildup and metallurgical changes.

Primary emphasis will be on fuel cycle imporvement by continued efforts on critical experiments, burnable poisons, fuel irradiation tests, existing core performance analyses, and improving designs for future cores. The overall plant system and components will continue to be

evaluated on performance and design characteristics. There is confidence that significant improvements will result which will directly benefit the water reactor concept and which will also provide supplementary technological advance to reactor powerplant systems in general.

Yankee Atomic Electric Co. (YAEC)

The YAEC plant is a pressurized-water reactor with an initial plant rating of 110,000 KWE. The primary loop pressure is 2,000 p.s.i.a. The steam conditions are 540 p.s.i.a. and 475° F. The research and development for this plant is well underway. The plant is scheduled for initial operation at the end of fiscal year 1960. The cost of research and development is financed by the AEC. Construction cost is financed by YEAC. The Yankee plant represents a second generation-pressurized-water plant. It is expected to provide sound cost and performance data on a large plant. The design takes advantage of experience with the Shippingport PWR but also includes significant technical variations which will improve the basis for evaluation of this type reactor and for planning its future development. These technical features include use of a uniform slightly enriched, stainless steel clad, long-life UO2 core and use of soluble chemical neutron absorbers for reactivity control from hot to cold conditions.

B. BOILING-WATER REACTORS

The essential feature of a boiling-water reactor is the production of steam in the reactor core. It is thus possible to reduce the pressure of the system and, in the case of a direct-cycle boiling reactor, to eliminate secondary equipment for steam generation. The reduced costs expected from these features must be evaluated against factors such as handling radioactive steam and load response characteristics.

The satisfactory results of research and development, the potential indicated by advance design, the excellent operating experience obtained on such small boiling-water reactor plants as the borax experiment, EBWR, and VBWR, and the design and construction experience on the large Dresden plant provide a major basis for the current optimism with respect to the probability that nuclear powerplants can be competitive with fossil fuel plants in significant areas of the United States within 10 years.

Specific activities in fiscal year 1960 in the Commission's program for the development of boiling-water reactors are described in the following paragraphs.

EBWR modification

The EBWR is a natural circulation, direct-cycle boiling-water reactor rated at 20 MWT at 600 p.s.i.a. The plant, currently operating at this power is generating 4,500 KWE net. It has been operated successfully for short periods of time at over 60 MWT. The EBWR will be modified to increase the power level to 100 MWT. No additional turbine-generator capacity will be added. Additional fuel spikes will be added to the core to increase the reactivity. Modifications are expected to start in June 1959 and be completed by December 1959. Operation at the higher power level will permit exploration of stability limits of small boiling-water reactor cores up to 58 KW/

Liter of core (75 KW/L of coolant). The core to be used for initial operation will consist of U–Zr metallic fuel. Plant modifications will make it possible to evaluate riser and chimney effects on the natural circulation rate. The plant also will be used to evaluate various fuel concepts, including irradiation of metallic fuel elements to exposures of perhaps 10,000 MD/Ton, and auxiliary plant problems, such as fuel rupture detection systems.

Borax V

Borax IV is shut down permanently. A new Borax facility will be constructed at Idaho, starting construction in June 1959 and scheduled for completion in June 1960. Borax V will be rated at 40 MWT at 600 p.s.i.a. The major contributions expected from this facility are expected to be: (*a*) performance data on nuclear superheat fuel and materials, (*b*) evaluation of forced versus natural circulation, (*c*) water chemistry studies as permitted by the flexible nature of the facility, and (*d*) core lattice studies.

Rural Cooperative Power Association (Elk River)

The plant consists of a natural circulation boiling-water reactor, a primary loop heat exchanger, a separate coal fired superheater, a turbine generator and associated equipment. The plant is rated at 22,000 KWE at 890 p.s.i.a. reactor pressure, the superheater outlet is 600 p.s.i.a. and 825° F. The reactor will utilize urania-thoria fuel. The reactor portion of the plant is being financed by the Commission. The turbine-generator and site is provided by RCPA. Plant construction was started in August 1958 and will be completed 1960. The plant is scheduled for full power operation in June 1961. The successful completion of this project will provide physics, heat transfer, irradiation and performance data on urania-thoria fuel. It will also provide performance and cost data on a small nuclear powerplant using an indirect, natural circulation, small boiling-water reactor coupled with a separate coal fired superheater.

Northern States Power

The plant consists of a direct cycle UO2 fueled, forced circulation, boiling water reactor that provides 600 psig saturated steam, by using a superheater the temperature is raised to 825° Fahrenheit before it goes to the turbine. The plant is rated at 66 MWE. The circulation pumps are variable speed so that the rate of circulation can be used as a method of reactor control. The reactor will incorporate mechanical steam separators inside the vessel. The cost of research and development on the Northern States plants is provided by the AEC. Plant construction costs are privately financed by the Northern States Power Co.

Research and development and establishment of a reference design for the boiling water reactor portion of this plant is underway. A proposal from Northern States Power to substitute nuclear superheat for the original proposal to superheat with fossil fuel has been approved by the Commission, and development and design work is underway on this modification.

Commission supported research and development will continue in fiscal year 1960. Construction of the plant will be initiated early in fiscal year 1960 with a scheduled completion date of June 1962. A critical facility will be completed, critical experiments will be initiated

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in fiscal year 1960. The successful completion of the NSP project will provide data on the performance and cost for a direct cycle, boiling water reactor, with integral nuclear superheat. The project also seeks to demonstrate the application of aluminum-nickel alloy clad for 600 psia saturated steam reactors and the feasibility of controlled recirculation as an effective means of control.

Advance boiling water prototype reactor

The Commission plans to augment the boiling water reactor technology by the construction of an advanced boiling water reactor prototype to explore and demonstrate several advanced steps whose realization would significantly reduce the cost of generating nuclear power from boiling water reactors. The prototype plant will have a power level appropriate to the demonstration of technology on a scale suitable for extrapolation to large central station powerplants. The design parameters are considered flexible at the present time in order that full advantage may be taken of results of research and development programs.

The plant will have the following design objectives: (*a*) Power density of 50 to 70 kw/L of core in a relatively large core using ceramic fuel elements, with prolonged operation (this is an increase by a factor of approximately two current design values for large cores); (*b*) fuel irradiation of 12,000 to 15,000 MD/ton with adequate core instrumentation to measure significant core parameters; (*c*) simplicity of design and ease of operation.

The reason for the deletion in the statement, Mr. Chairman, is that this plant will not in view of the Northern States development include nuclear superheat.

Turning to heavy water moderated reactors, the use of heavy water as a moderator is of interest because it allows high neutron economy which makes possible the use of normal or only slightly enriched fuel and which may result in other reductions of fuel cycle costs. The possible use of natural uranium fuel is of special interest in countries which do not have enrichment plants. The high moderator to fuel ratio required by the nuclear characteristics of heavy water moderated systems leads to relatively large reactor cores even in reactors of low power ratings. A high coolant pressure is desirable for thermodynamic reasons. The problems of producing large vessels capable of withstanding high pressures will place more severe limitations on the power level of pressure vessel type heavy water moderated and cooled reactors than on those using ordinary water. This unique characteristic of heavy water moderated reactors leads to consideration of a pressure tube design with high pressure in the coolant tubes and a relatively low pressure moderator outside the tube. This makes it possible to contain the heavy water moderator in a low pressure tank with no practical size limitations. Pressure tube designs have additional potential advantages in that they facilitate monitoring of individual fuel channels, ease limitations on rate of temperature change and facilitate fuel shuffling.

The Commission is working toward a more extensive cooperaive program with the Canadians which will help advance the development of heavy water moderated reactors operating on natural uranium. A formal program for maintaining close cooperation in the development of heavy water moderated power reactors has been in existence

with the Canadians for about 2 years. This program has provided for exchange of information, and technical personnel and for the use of irradiation facilities. The Canadians have in operation two heavy water moderated experimental reactors which have provided extensive irradiation service for some of the program activities of the United States. A prototype heavy water moderated and cooled reactor of the pressure tube type is presently under design and construction in Canada. A large reactor of this type would be capable of operation with natural uranium and Canadian plans include the development and construction of a large power reactor based on the results obtained from this prototype. In view of the special incentive which the Canadians have to develop this concept and their acknowledged competence in the technology of heavy water reactors, it is clear that the most rapid advancement of this technology can be achieved through a cooperative effort not only in research and development but also in design and construction activities.

The special interest of other countries in reactors which will operate on natural uranium is recognized not only in cooperation with the Canadians but also in participation of representatives of other groups in the present program of the United States. For example, the design study currently in progress on heavy water moderated reactors operable on natural uranium includes particpation by representatives of Sweden, OEEC, and Euratom.

Some of the specific activities in fiscal year 1960 in the Commission's program for the development of heavy water moderated reactors are described in the following paragraphs. Other related activities are summarized in connection with discussions of specific coolants.

Heavy water components test reactor (HWCTR)

The HWCTR is a 60-megawatt-thermal pressure vessel-type reactor, cooled and moderated with heavy water. Developments, design, and construction will continue throughout fiscal year 1960 with construction scheduled for completion in February 1961. The HWCTR is being designed as a versatile experimental reactor to test and evaluate fuels, systems, and components being considered and developed for use in large-scale heavy water moderated power reactors. There are provisions for six separate test loops so that various coolants and associated fuel elements may be evaluated simultaneously. The facility will be used to test a number of uranium metallic and ceramic fuel elements, to determine and minimize heavy water leakage, to evaluate heavy water purification components, to determine means for handling tritium produced by irradiation of deuterium, to test component connecting seals, to evaluate heavy water heat exchanger design, and to determine the adequacy of developed instrumentation for detection of fuel element behavior and failures.

Plutonium recycle test reactor (PRTR)

The PRTR is being constructed to serve as an experimental facility for demonstration and evaluation of the plutonium recycle concept. The PRTR is a 70-megawatt-thermal heavy water moderated and cooled pressure tube reactor. This reactor design was selected for use in the plutonium recycle program primarily for its ability to serve as a versatile fuel recycle facility. However, the development, construction, and operation of the PRTR will provide byproduct benefits to

heavy water moderated power reactor technology. The reactor plant is scheduled for completion early in fiscal year 1961.

In addition to its contribution to the basic plutonium recycle objective, some of the PRTR design features are expected to make significant contributions to general power reactor technology. These include the use of zircaloy-2 pressure tubes, stainless steel to zircaloy-2 connections, reactor control by regulation of heavy water moderator level through a gas balance control system, improved heavy water circulating pumps, and fuel channel monitoring system.

Carolinas Virginia Nuclear Power Associates (CVNPA)

The Commission is providing research and development support to Carolinas Virginia Nuclear Power Associates who will construct a 17-MWE heavy water moderated pressure tube reactor fueled with slightly enriched uranium dioxide. Steam from the reactor will be fed via a fossil-fueled superheater to an existing electrical generating plant. Construction is scheduled to begin in mid-fiscal year 1960 and will be completed by June 1963. Research and development during fiscal year 1960 will include work on materials and fabrications methods for pressure tubes, high integrity seals, improved fuel elements and the physics of heavy water moderated, clumped uranium oxide lattices. The reactor, which will serve as a prototype of a large scale reactor optimized for minimum cost power for this type under conditions of private utility financing in the United States, will provide design and operating experience required to determine the economics and technical feasibility of building and operating the full-scale plant.

An important aspect of the research and development work is the development of fuel pellets containing a core of a high melting ceramic. Use of this type element permits operation at higher surface temperatures without center-line melting. This reactor will be the first designed for electrical utility application in the United States using pressure tubes.

II. ORGANIC COOLED REACTORS

Organic materials are of interest for use as moderator and coolant or as a coolant in combination with some other moderator such as graphite or heavy water. Reactors using organic fluids as both moderator and coolant have a range of applicability comparable to that of water reactors. There is a somewhat less serious limitation on large size for reactors using organic materials in place of water because of the lower pressure of the primary system for given steam conditions.

The chemical compatibility of organic with fuel and structural materials and the nonradioactive nature of the primary system offer promise of lower construction costs. This must be balanced against the cost of makeup for loss of decomposition of the organic material. Only by actual operating experience can this balance be truly evaluated. At this time estimated costs from large scale organic cooled reactors are in strong competition with those from other systems which are under intensive development.

Use of the organic as only a coolant rather than as coolant and moderator reduces the cost of makeup and retains the advantage of chemical compatibility and low pressure in the primary system. De-

velopment of organic coolant technology could have important by-product value for systems in which low shielding weight and absence of radioactivity from the primary system are of special significance.

The low thermal conductivity of organic materials relative to water does not appear to be a serious handicap at the present time, since limitations imposed by the low thermal conductivity of oxide fuels are preventing use of the full potential of water as coolant.

Specific activities proposed in fiscal year 1960 to advance the development of organic cooled reactors are summarized in the following paragraphs.

Organic moderated reactor experiment (OMRE)

The OMRE will be operated for extended periods to allow the concentrations of various organic compounds formed by irradiation to come to complete equilibrium at the temperature conditions planned for the reactor to be built at Piqua, Ohio. Subsequent runs at power levels up to 15 MWT will be made to determine the maximum fuel surface and organic outlet temperatures permissible with the organic coolant under test. During these runs several Piqua-type fuel segments will be tested in the reactor. During the latter part of fiscal year 1960 a full core loading of Piqua-type metallic uranium fuel elements may be installed in the reactor for more complete evaluation.

Piqua

The Commission will proceed with the construction of an organic moderated and cooled reactor at a new site in Piqua, Ohio. Construction and operation of this reactor, scheduled for completion in the fall of 1961, will provide cost and operating data for a small nuclear powerplant (10,000 KWE) using this type reactor. This project is expected to provide further demonstration of ease of maintenance and reliability of components under routine operating conditions. This type reactor is considered to be one of the more promising for small-plant application. Additional fuel irradiation experience provided by the plant at Piqua will be an important contribution.

We have one disappointing problem in connection with the Piqua plant, and that is—apparently to satisfy the thoughtful judgment of the safeguards committee—we must put a container on their plant at an additional cost of several hundred thousand dollars, and this is a discouraging development which causes me to qualify to some extent the statement.

Chairman ANDERSON. That is a recent development?

Mr. MCCONE. It is a recent development; yes.

Experimental organic cooled reactor

An experimental organic cooled reactor will be built starting in fiscal year 1960 to supplement the OMRE and the Piqua reactor. The OMRE is a limited-purpose facility in which one organic material at one temperature can be tested at one time. It was designed for simple observation of decomposition rates and surface fouling behavior under power reactor conditions of temperature and radiation. The lack of fuel element handling facilities further limits the usefulness of the OMRE. The Piqua reactor will be operated on a power network to obtain operating experience and cost information. It is neither designed nor intended for use as a highly flexible experimental

reactor. The number of promising coolants, possible moderators, and the possible temperature conditions and consequences require that a large number of tests be made to find the optimum conditions for operation of organic cooled reactors.

The experimental organic cooled reactor proposed will have an operating level in the range of 20 to 40 MWT. It will provide a reactor facility for determining technical data which will make it possible to design plants for more nearly optimum conditions. It will also provide for extensive tests of possible fuel elements. It will facilitate test design features of advanced reactors such as nucleate boiling in the organic coolant. The data provided by this plant will contribute directly to the knowledge required to increase the specific power of organic reactors, to increase the thermal efficiency and to lower the fuel cycle costs. Achievement of these technical objectives will in turn contribute to the achievement of economic power with organic cooled reactors.

III. GAS COOLED REACTORS

Gas cooled reactors offer immediate promise of providing steam conditions consistent with modern practices of the utility industry at fuel costs which may be lower than achievable with water cooled systems. Gas cooled reactors offer development potential to provide very high temperature coolant which may be of interest in connection with operation of closed cycle gas turbines, or ultimately for application to high temperature industrial processes.

The low specific power and consequent high capital cost of gas cooled reactors considered technically feasible until recently made gas look relatively unattractive as a power reactor coolant under economic conditions of the United States. Through programs carried out in our own laboratories in both the civilian and military reactor fields, through our cooperative efforts with the British in gas cooled reactor technology, and through work done by American industry, the way has been pointed toward the possibility of achieving higher specific powers and of realizing capital costs comparable with those of other reactors now under development. Because of the promise now offered by gas cooled reactor systems, the Commission is prepared to embark upon an extensive program for the development of advanced gas cooled reactor technology.

Gas cooled reactors using graphite as moderator have received major attention so far, but systems using other moderators, such as heavy water, also are under development. Some gas cooled reactor design variations are based upon operation with natural or partially enriched uranium while others are based upon operation with fully enriched uranium mixed with thorium. None of the systems is considered to be a breeder reactor, although some contemplate large effective fuel burnup through thorium conversion.

All large plant operating experience to date has been that of the British on graphite moderated systems using carbon dioxide as coolant and natural uranium fuel. Temperature limitations of the metallic fuel and temperature effects on reaction rates between carbon dioxide and graphite make these systems appear economically unattractive in the United States with present technology. Designs seeking very

high temperature, in general favor us of helium as a coolant. Helium supply is believed to be adequate for such reactors to play an important part in the nuclear power industry if technical problems of the reactor designs can be solved.

Specific activities with respect to gas cooled power reactor development proposed for implementation in fiscal year 1960 are summarized in the following paragraphs:

East Central Nuclear Group—Florida West Coast Nuclear Group (ECNG–FWCNG)

The Commission has accepted a proposal of ECNG–FWCNG for development and construction of a gas cooled heavy water moderated prototype power reactor. Under this arrangement the Commission will share research and development costs with the proposers in accordance with agreed ceilings and will waive use charges for special nuclear material and heavy water for a period extending through the initial 5 years of plant operation. Cost of the plant will be borne by the FWCNG.

This reactor uses pressure tubes, carbon dioxide coolant with an exit temperature of about 1,000° F., and partially enriched uranium oxide fuel. The plant will have a capacity of 50 MWE and will be designed as a prototype of a large-scale plant capable of operating on natural uranium fuel. In view of the special interest in operability on natural uranium the development program includes consideration of beryllium as cladding although initial operation probably will be with stainless steel cladding developed largely in connection with other programs. During fiscal year 1960 the program will consist of conceptual design studies and research and development on fuel elements and plant components, including in particular pressure tube technology.

Experimental gas cooled reactor

The Commission currently is designing and will construct a graphite moderated gas cooled experimental reactor fueled with low enrichment uranium. The major purpose of this plant, which is based on a modification of the prototype power reactor design prepared by Kaiser-Engineers-ACF Industries, is to advance the technology of gas cooled reactors on a broad front by providing capability for testing advanced fuel elements, materials, and components. It will have sufficient electric generation capacity to explore problems of operating such a gas cooled reactor as part of a nuclear powerplant but will not serve as a true power producing prototype. The plant will be built in a minimum time consistent with all engineering considerations with initial operation planned for late 1962. It will have an exit gas temperature of 1,000° to 1,200° F. and an output rating in the range of 50 to 86 MWT.

High temperature gas reactor

The proposal of Philadelphia Electric & General Dynamics will be accepted as a basis for contract negotiation. The research and development and reactor construction to be accomplished under this project seeks extension of gas cooled reactor technology to use a homogeneous mixture of uranium and thorium carbides in graphite to provide an exit gas temperature of about 1,400° F. The reactor,

which will operate on the Philadelphia Electric system, will have an initial power level of 28 MWE using metal clad elements but is expected to produce 40 MWE with unclad elements.

IV. SODIUM COOLED THERMAL REACTORS

The unique contribution of sodium cooled thermal reactor systems is high thermal efficiency coupled with very low primary system pressure. With proper fuel development the use of sodium as a coolant can also lead to higher specific power than any other type of coolant. Radiation from the sodium requires heavy shielding of the primary coolant system and introduces some difficulty in connection with plant maintenance. However, it may actually develop that this radiation will have value as a byproduct.

The principal area of development of sodium cooled thermal reactors uses graphite as the moderator. However, sodium may also be used in connection with other moderators such as beryllium, beryllium oxide, or heavy water. Graphite moderated systems, in particular, are expected to have favorable economics only in large size plants. The high temperature and other characteristics associated with sodium cooled systems introduce new fuel element development problems. Assuming these problems can be solved, either uranium or thorium fuel cycles can be used. While breeding is not possible in sodium graphite reactors, use of an intermediate spectrum with thorium fuels may lead to high conversion ratios.

Components in the sodium coolant system are of direct application to fast breeder reactor systems now under development and continued development of these components can be justified under either program.

Sodium cooled thermal reactors or those operating in the intermediate neutron energy range are not considered as capable of achieving competitive power costs as soon as they may be achieved by other reactor concepts in the program. However, in the very large sizes which can be developed for the future they are expected to have a definite economic advantage over those systems which may first achieve economic power.

Specific activities planned for fiscal year 1960 in the development of sodium are described in the following paragraphs:

Sodium reactor experiment (SRE)

A new core consisting of thorium with 7.6 weight percent of U^{235} will be loaded in the SRE soon. The potential of this fuel as a high integrity, high burnup, high temperature material will be carefully evaluated. The reactor will continue to be used extensively as a fuel test facility during fiscal year 1960. Mixed clusters of fuels such as U–Mo and UC will be installed in the six experimental holes. Low power oscillator tests and other physics experiments will continue in order to study the behavior of sodium graphite reactors. Modifications will be made in the zirconium cans which contain the graphite if necessary to improve their resistance to thermal cycling.

Experimental sodium cooled reactor

In fiscal year 1960 the conceptual design of an improved sodium reactor experiment will be started. If constructed, this reactor would

seek an improvement over the SRE of perhaps 25 percent in power density and major improvement in arrangement of plant components. It would have an output of about 40 MWT. This reactor would be built around a core design which obviates the need for individual canning of graphite blocks. It would provide a better neutron economy and a cheaper moderator arrangement. This concept would include a novel sodium overflow design and electromagnetic pumps, the main parts of which are accessible and shielded from radioactive sodium. The intermediate heat exchangers would be of an annular configuration and would be located inside of the reactor tank. Design simplifications are expected to make this reactor relatively inexpensive.

If constructed and operated, this reactor would confirm the possibility of a radically improved sodium graphite system economics, by reduced capital costs, simpler operation and maintenance, and reduced fuel costs through improved neutron economy.

Hallam nuclear power facility

The Commission is exploring with the Consumers Public Power District of Nebraska the advisability of delaying the construction of a 75 MWE sodium cooled, graphite moderated reactor, which is now scheduled for initiation in fiscal year 1960 at Hallam, Nebr., in order to take full advantage of the technological and economic improvements which can be built into a sodium cooled reactor as a result of operation of the ESCR discussed previously. Under the present arrangement CPPD will provide the turbine generator plant, will contribute to the cost of the reactor an amount equivalent to the cost of a conventional boiler, and will operate the plant. The current reactor design is based upon design and operating experience with the sodium reactor experiment.

The Hallam project, whether based on existing or advanced technology, will provide design, construction and operating experience with a prototype sodium graphite reactor which can be interpreted in terms of a large central station nuclear powerplant. In addition to testing large systems components under routine plant operating conditions, the plant will facilitate testing of large numbers of fuel elements designed for operation at high temperature.

I would like to say that I have had a number of discussions and the staff have had discussions with the management of the Consumers group. They are very anxious to explore the advantages to themselves and the program of the delay in this project, although they do want the reactor in their system at a proper time.

Representative HOLIFIELD. How about the manufacturers of the equipment?

Mr. MCCONE. I have not discussed it with them.

I will turn now to fluid fuel reactors.

The fluid fuel reactors development program includes the development of aqueous homogeneous reactors, fused salt reactors, and liquid metal fueled reactors. There are three features or potential characteristics common to all fluid fuel reactor systems that are of particular interest. These are (*a*) elimination of fuel fabrication, (*b*) long equivalent fuel irradiation cycle, and (*c*) high specific power. In addition systems using heavy water offer promise of high neutron economy, and the liquid metal and fuzed salt systems offer potential of high

thermal efficiency with low system pressure. The combination of high specific power and high neutron economy leads to the interest in aqueous homogeneous reactors as perhaps the only real possibility of breeding on the U^{233} thorium fuel cycle with a reasonable doubling time.

Recent experience with the homogeneous reactor experiment No. 2 (HRE–2) has been somewhat discouraging in that instability of the fuel solution, probably brought about by overheating of localized stagnant regions in the reactor core, has led to failure of the reactor zirc-alloy core tank and to fluctuations in reactor power level during operation.

In December of 1958 the Westinghouse Electric Corp. and the Pennsylvania Power & Light Co. withdrew their proposal to develop and construct a 150 MW (E) aqueous, single-region slurry reactor (PAR). This decision was brought about by the combined uncertainties in technical feasibility existing in several areas of the plant design, and the high investment risk associated with proceeding immediately to full scale plant construction.

Despite these temporary setbacks in the aqueous program the prospects of achieving low nuclear power cost and thermal breeding with fluid fuel reactors through long-range development effort still looks promising.

The Commission has undertaken a major reevalution of the existing fluid fuel reactor programs. Research and development directed primarily toward basic problems in chemistry and metallurgy will continued during fiscal year 1960, at a rate adequate to meet present needs consistent with technological uncertainties. Operation of the HRE [2] will continue during at least part of fiscal year 1960 in order to gain improved understanding of fuel solution behavior and additional operating experience on reliability of components and experience in maintaining radioactive systems. Construction of additional fluid fuel reactor experiments is not contemplated for fiscal year 1960.

VI. FAST BREEDER REACTORS

The unique contribution of reactors operating on fast neutrons is one of breeding on the plutonium-uranium fuel cycle. The development of reactors which can utilize both fissionable and fertile materials is essential to the long range program. The successful achievement of economic breeders will greatly increase the amount of energy available from nuclear fission to supply continued expansion in the energy demands of the world. The development of fast breeder power reactors is one of the major long range objectives in the power reactor development program of the United States.

Utilization of both fissionable and fertile isotopes of uranium in fast reactors is possible because of the following factors: (*a*) Approximately 15 percent of the energy produced can be obtained by the direct fissioning of U^{238}; (*b*) neutron economy is high because reactor materials of construction have low neutron capture cross sections in the fast neutron spectrum relative to fuels, and (*c*) plutonium's nuclear characteristics are favorable for use as a fuel in fast reactors.

The achievement of reasonable doubling time with fast power breeders depends upon solving many engineering problems associated with achieving a very high specific power in a fast reactor.

The Commission's fast breeder power reactor revelopment program includes many activities on fuel cycle research, reactor safety studies, and reactor design, construction and operation. The reactor safety work includes an investigation of the meltdown characteristics of fast reactor fuel pins in the transient Reactor Test Facility (TREAT).

Experimental breeder reactor No. 1 (EBR–I)

Operation of the Experimental Breeder Reactor will continue during fiscal year 1960. Additional physics data and stability data will be obtained with the MARK III core including effects of further loosening of the fuel elements in this core. The next core for EBR–I will be a plutonium alloy core which will be fabricated and charged during fiscal year 1960. This event will mark progress in an important transition of fast breeder reactor development toward the use of plutonium fuels.

EBR–II

Construction of the EBR–II at the National Reactor Testing Station will continue throughout fiscal year 1960 and is expected to be completed by fiscal year 1960. Major effort will be exerted toward completion of the reactor building, the powerplant, and a supporting laboratory; construction of housing for the unique steam generator and the integrated remotely operated, fuel cycle reprocessing and refabrication facility will be started. Procurement activity in support of the project will continue through fiscal year 1960.

The EBR II is a key facility in the Commission's long range program. It is designed for an output of 20 MWE. It will demonstrate, on a prototype scale from which commercial design may be extrapolated, the technical feasibility of safely operating a fast breeder reactor under conditions of moderately high power density at a thermal efficiency comparable with modern fossil-fueled steam plants. In addition, EBR II with its integrated fuel reprocessing and refabricating facility, will demonstrate for the first time the refabrication and recharging of fissionable material bred in a reactor.

Development of remotely operated pyrometallurgical reprocessing and refabrication techniques for the EBR II complex has reached the proof testing phase. During fiscal year 1960, prototype fuel handling equipment, which will later be installed at EBR II, will be used at Argonne National Laboratory for the dual purpose of fabricating core components and training operators for the facility.

Enrico Fermi plant

Research and development in Commission laboratories applicable to the PRDC plant will continue in fiscal year 1960. This work will include critical experiments, fuel development, and fuel irradiations. The Enrico Fermi nuclear powerplant, if it is licensed and operated at full power will be the largest fast breeder anywhere in the world. The plant is under construction with private funds. It will be the first fast breeder reactor to produce power for a utility system.

The existence and operation of this plant will provide information supplementary to that obtained from other efforts in the development of fast reactors and large sodium components. The approach which the designers have taken in solving important technical problems

such as plant arrangement and component design, including fuel elements, differs from approaches of other designers. Thus, the probability that satisfactory solutions to these problems will be found in the overall effort is improved by the existence of this project.

Small powerplant

The Commission recognizes the importance of small powerplants in supplying energy requirements both in the United States and abroad. The Commission therefore has initiated an intensive study to determine what reactor concepts offer the greatest short and long-range promise for producing power at reasonable cost in small plants (5 to 40 MWE). Plants of this type would be suitable for use by utilities, including municipalities and for the export market. The Commission will initiate design and construction of a small nuclear powerplant with a capacity of about 20 MWE in fiscal year 1960 unless the studies clearly indicate that this is not appropriate at the present time.

VIII. PROCESS HEAT REACTORS

Continuing development of power reactor concepts has shown that it is technically feasible to construct reactors operating at a relatively low temperature. Heat from such reactors should find wide application in the various heat using industries, like the paper pulp and the chemical industry. Industrial acceptance of such an alternative heat source has not yet been obtained. In these industries the cost of heat represents only a small fraction of the cost of the product. In addition, early obsolescence of the chemical processes themselves have forced the industry to minimize any risks not associated directly with the process. Therefore, there is an understandable reluctance by industry to invest the sums required in process heat reactors until their economic attractiveness has been demonstrated by actual plant operation.

To demonstrate this economic attractiveness the Commission has been supporting a number of activities and expanded efforts are planned. Several market surveys have recently been completed for the Commission defining process heat requirements by industries in the United States. A study team at the Argonne National Laboratory is evaluating reactor concepts to determine which are most suitable for process heat applications.

The Commission will initiate design and construction of a low temperature process heat reactor in fiscal year 1960 to serve as a demonstration of the technology performance and economics of such a plant. The design of this plant will incorporate the reactor concept selected as having the greatest potential for this application.

The Commission is cooperating with the Department of Interior in working on the problem of the conversion of saline waters to potable waters for irrigation and other purposes. The construction of a nuclear reactor as the heat source in a saline water conversion demonstration plant is seriously being considered by the Commission as an alternative to the construction of a process heat reactor at a Commission site.

In summary, the program which I have outlined aggressively implements the objectives for developing competitive nuclear power in the minimum time. I favor construction of power generating proto-

types which can be built and put in operation in 2 or 2½ years as a much more rapid approach and more economical approach for demonstrating technical progress than any other course we can follow. Large plants unfortunately require much more time to finance, engineer, and construct. Moreover, when once in operation, are less flexible and therefore not adapted to proving technical advances. I believe time is of the essence and I therefore urge favorable consideration of our proposals.

We anticipate continuation of many, but not all, projects initiated in prior years. Some are to be modified and the new projects should be initiated immediately. The attached table summarizes the course of action the Commission proposes to follow. Permissive authorizing legislation has been requested of this committee. Adequate funds are available or included in fiscal year 1960 budget.

I would like to add the following comments:

Pressurized water concept is well advanced. Shippingport is a most useful prototype. It will serve for the next several years to develop and improve the fuel cycle. Lower power costs resulting from lower plant costs and more efficient fuel will result. The nuclear power naval vessels, 33 submarines, 1 destroyer, 1 cruiser, 1 aircraft carrier with 8 power reactors and the *N. S. Savannah*, all pressurized water design, the 110-megawatt plant to be built in Italy of U.S. design insure significant evolutionary developments in this field. It is our judgment, as well as the judgment of principal engineering firms and operators, that emphasis on fuel element development is of greatest importance. No other area for cost reduction seems as promising to me. For that reason, a major portion of the $20 million we are spending at Shippingport this year and an equal amount requested in fiscal year 1960 is for this purpose. No additional pressurized water prototype is indicated as being necessary.

In the boiling water reactor several promising steps are being taken. The modification of the experimental boiling water reactor at Argonne, originally designed for 20 megawatts thermal, and now operated at 60 megawatts thermal, is now being modified to produce 100 megawatts thermal, or five times the design criteria.

The reactor experiment, BORAX–V, is being designed and constructed at the AEC testing station in Idaho to develop nuclear superheat. The Northern States Power reactor now being constructed in Sioux Falls, S. Dak., will be equipped with a nuclear rather than a conventional superheater. This is a major step forward.

Two new boiling water projects are expected to be undertaken. First, a prototype which will incorporate all known improvements in this process in power density, fuel life and design simplicity. This plant will lead the way to commercially feasible developments and can be completed in about 2 or 2½ years.

In addition, we plan to initiate studies on a very simple economical plant of small size, probably boiling water, and to immediately construct a prototype if studies warrant. An economical small plant will be of great service to the Rural Electrification Authority, to modest size public and private utilities, and to foreign countries. Mr. Cole of the International Atomic Energy Agency is pleading for our help in this area.

We will initiate a gas-cooled reactor program designed to place this country in the forefront in this most promising field. Specifically, we plan to complete the designs and construct an experimental gas-cooled reactor which can test natural and partially enriched uranium fuel elements at temperature ranges of 700° to 1,200° F. Power will be produced and if satisfactory arrangements are worked out will be fed into a power system to develop compatability of the gas-cooled reactor system and demands of a power grid.

We propose to accept the Philadelphia Electric Co.'s proposal to build a high temperature gas-cooled reactor of about 40 megawatts. We will support this project with research and development assistance. I emphasize that this is a courageous step forward for both the Commission and industry. We have confidence that it will be successful, and when this reactor is completed in mid-1963,[1] the United States can expect to be several years ahead of other countries in this very important nuclear power development.

Organic cooled reactor development will be continued. The favorable results obtained from our present organic test reactor warrant further experimentation. A second experimental reactor will be designed and constructed immediately. Concurrently, we will go forward with the design and construction of a small plant at Piqua, Ohio. The technology which will be developed from these plants should determine the promise of this process and indicate the further support which might be warranted.

The sodium-cooled, graphite moderated thermal reactor system is to be continued. One reactor experiment now operating successfully at Santa Susana will continue to provide useful developmental information. Conceptual design on a second reactor experiment incorporating all known improvements will start in preparation for the construction of such a unit if engineering considerations warrant. The presently authorized 75 megawatt plant for the Consumers Public Power District of Nebraska will be built promptly unless the indicated technological advances warrant, in the opinion of the Commission and the Consumers Public Power District, a delay. This plant is estimated to cost the Government $50 million for research, development, and construction, and about $2 million per year in operations thereafter. The Commission believes that expenditures of this magnitude demand concerted effort to insure construction of the most advanced and promising plant of the sodium-graphite type at Hallam.

(A letter from Dr. Chauncey Starr, North American Aviation, Inc., dated February 20, 1959, regarding the possible effects of delay in the Hallam project, follows:)

ATOMICS INTERNATIONAL,
February 20, 1959.

Hon. JOHN A. MCCONE,
Chairman, U.S. Atomic Energy Commission,
Washington, D.C.

DEAR MR. MCCONE: In view of the recent interest of the Commission in considering the possibility of delaying the Hallam Nuclear Power Facility, it may be of interest to you to have our summary of the technical and economic aspects of this problem.

The enclosed table summarizes the effects on performance and schedule of the major technical improvements which might be contemplated for inclusion in the Hallam plant in the next several years if the construction of this plant

[1] Construction completed June 1963, full-power operation June 1964.

were delayed. The table is divided into three sets of columns. The first refers to the present Hallam plant design, operating at its normal rating, and also at the estimated peak of performance which the present design might permit. The second group of columns involves primarily a substitution in the present plant design of a new core of the "calandria" type. This core permits a better neutron economy. Improvements in the steam cycle and turbine combination which might subsequently be added are presented for comparison. The last set of columns refers to the Advanced Sodium Graphite Reactor which is a very radical engineering modification of the whole sodium system. This concept has been proposed for the experimental sodium-cooled reactor as a means of achieving major capital cost reduction in the sodium system. The cost estimates for large plants of this type are necessarily quite rough at this time. These estimates are presented for both a 100 MWe and 250 MWe plant as a matter of comparative interest.

As the table indicates, the present Hallam plant should produce power at about 12.4 mills per kilowatt-hour at its rated conditions, with possibly a mill saving as the performance is improved with time. By delaying the program approximately 1½ years a calandria core might be substituted which would then bring the power costs down to 10.6 mills per kilowatt-hour, with subsequent improvement if the steam generators and steam turbines could be appropriately modified. A 3-year delay might permit the construction of the advanced SGR with an estimated cost of power of 8.9 mills per kilowatt-hour.

Each one of the modifications of the Hallam plant will require some new research and development work in order to investigate the redesign of the steam generators and the other conditions which the higher temperatures create.

It is of course pertinent to the long-range planning of the Commission's reactor program that the advanced SGR concept (if successfully demonstrated by the proposed reactor experiment) would permit the production of electrical power in central station sized units which approaches economic competition with conventional plants. As you know, we have consistently believed that the advantages of liquid sodium as a coolant warrants faith in this approach to future economic power, even though the present Hallam costs are higher than those desirable for competitive purposes.

In examining the costs associated with delaying the Hallam program, the following may be of interest. As of March 1, 1959, about $7 million will have been spent by our organization, Bechtel, and Consumers, in the engineering, development, and testing for the Hallam plant. Although a good portion of this would continue to be useful if only the calandria core modification were undertaken, most of this would have to be redone if the advanced SGR concept were substituted. In addition, about $4.5 million of procurement for research and development and construction commitments will have been incurred by March 1. We estimate that the cost of stopping this activity to be approximately $1.5 million. Thus, if the program were delayed a full 3 years to incorporate the advanced concept, approximately $8.5 million of incurred costs will not be applicable to the new plant. This $8.5 million would represent a loss to the program which would have to be replaced in order to permit the equivalent engineering for a new plant.

Of the total approved Hallam program, about $24.5 million represented the AEC's expenditure for construction. Presumably the funds allocated to research and development would continue to be applied to the project with the addition of the sums necessary for the testing of new concepts and components.

Although an advanced SGR could probably be built for somewhat less than the present Hallam concept, the effects of escalation (and any penalty payments made to the Consumers Public Power District) would have to be added to the moneys required for this project. It is likely that a 3-year delay at the present rate of escalation would increase the basis cost of the plant by about 21 percent, based on the BLS Steel Mill Product index. For all the above reasons, it is evident that such a delay will result in a substantially increased cost to the Government for the project.

Recognizing that the Commission's objective for this program is primarily the most rapid approach to the demonstration of economically competitive power, we have considered the effects of the three alternate approaches discussed in the table on the program status in 1965. We have assumed that in any event the Commission would provide continued support for the experimental sodium-cooled reactor for the testing of the advanced concept, would continue the support of the general sodium technology program, and

would continue the support of the Commission's sodium steam generator program. All of the above are key portions of the technical progress in this field.

First, if the Hallam plant were built according to schedule, we would have by 1965 the demonstrated experience by a utility in the operation of the world's largest liquid sodium power system and, in addition, the experimental verification of the advanced SGR concept. By late 1962 one might expect the Hallam plant to produce 90 MWe with steam conditions (850 p.s.i., 870° F.) which are higher than those of any reactor now ready for construction. In addition, the Hallam plant would provide the first large-scale statistically important test on several fuel materials at high operating temperatures.

If the second approach of substituting the calandria core is followed, the practical demonstration of large-scale operation will have been delayed by about 1½ years without substantially contributing to the verification of the advanced concept. For this reason, it appears to me that while the second approach might provide slightly better performance, it does not materially advance the technical art, and thus does not warrant the delay.

If the third approach of delaying the program for 3 years and constructing the advanced SGR is followed, we will have at that time completed the demonstration on the experimental plant of this advanced concept, and we will be placing into operation a prototype of the best conceptual thinking we presently foresee. However, we will not have provided the operational experience on a large sodium plant or the fuel element experience which the present Hallam schedule could give us by that date. In addition, placing the advanced concept into operation on a large prototype at that time represents a technical projection with greater technological risks, because of the radical nature of this concept.

An additional factor which has been startling demonstrated in our engineering and procurement for the Hallam plant is the fact that vendors of large engineering equipment do not give detailed and serious consideration to the special devices necessary for the nuclear plants until such time as a bona fide procurement operation is undertaken. We have had several instances of the significant difference between early estimates and final prices with several major components. Although in some cases the price of the components increased (as was notably true in the steam generators) as soon as we asked for serious quotations, we have had compensating reductions in cost in major items as soon as the vendors felt that it was worth their time to really competitively examine manufacturing techniques and the like. In our opinion, the construction of the Hallam plant would therefore have the qualitative but very real benefit of forcing realistic analyses of nuclear equipment manufacture by the principal vendors. The effect of this would be to not only materially improve the quality of engineering design in the future plants, but also to increase the realism and the degree of confidence which can be associated with future cost estimates.

For the above reasons, it is my opinion that the objectives of the Commission in demonstrating the practical economics of nuclear power are best achieved by constructing the Hallam plant on its present schedule and continuing the development programs as outlined above.

Sincerely yours,

C. STARR, *Vice President.*

SGR comparison, Feb. 20, 1959

	Hallam Nuclear Power Facility		Hallam Nuclear Power Facility with calandria			Advanced Sodium Graphite Reactor [1]	
Net electrical rating ..... MW	75	87.5	87.5	94	110	[15] 250	100
Gross electrical rating ..... MW	[2] 81.8	[3] 95.0	[3] 95.0	[4] 104	[5] 120	270	110
Estimated plant power ..... MW	6.8	[6] 7.5	[6] 7.5	10	10	20	10
Reactor thermal power ..... MWt	240	263	263	238	280	615	247
Sodium outlet temperature ..... ° F	945	1,000	1,000	[16] 1,100	[16] 1,100	[16] 1,150	[16] 1,150
Steam conditions ..... { p.s.i.g.	800	850	850	1,450	1,450	2,400	2,400
Steam conditions ..... { ° F	825	870	870	[7] 1,000	[7] 1,000	[7] 1,000	[7] 1,000
Estimated date at rated conditions	7/62	[8] 1/63	1/64	1/65	1/65	.....	7/65
Net plant efficiency ..... percent	31.2	33.2	33.2	39.5	39.5	40.8	40.5
Fuel—For cycle costs	[9] UC	[9] UC	UC	UC	UC	UC	UC
Additional R. & D. ..... 10⁶$	.....	.....	2	4	4	.....	6
Capital costs:							
Nuclear plant ..... 10⁶$	29.7	29.7	29.7	32.5	32.5	37.5	28.5
Turbogenerator ..... 10⁶$	10.3	10.3	10.3	10.5	10.5	22.5	9.5
Total	40.0	40.0	40.0	43.0	43.0	60.0	38.0
Nuclear plant ..... $/net kwe	396.0	339	339	345	296	150	285
Turbogenerator ..... $/net kwe	137.5	118	118	112	[10] 95	90	95
Total ..... $/net kwe	533.5	457	457	457	391	240	380
Power costs:							
△From base case—Neutron eff. ..... mills/kw-hr	.....	0	−0.5	−0.5	0.5	−0.5	−0.5
△From base case—Thermal eff. ..... mills/kw-hr	.....	−0.2	−0.2	−0.7	0.7	−0.8	−0.8
Capital [11] ..... mills/kw-hr	7.6	6.5	6.5	6.6	5.6	3.4	5.4
Fuel [12] ..... mills/kw-hr	[13] 3.8	3.6	3.1	2.6	2.6	2.5	2.5
Operation and maintenance ..... mills/kw-hr	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Total ..... mills/kw-hr	12.4	11.1	10.6	10.2	9.2	6.9	8.9

[1] New plant including calandria and new turbine.
[2] Nominal rating.
[3] Maximum design rating with 1,000° F. Na.
[4] Nominal rating of original turbine.
[5] Maximum design rating of original turbine.
[6] Nuclear plant losses estimated from nominal rating, turbogenerator plant ratioed by steam flow.
[7] Reheat cycle.
[8] Date—1/64 if UC is needed to reach 1,000° F. Na.
[9] Plant start-up with U–10 without Mo replacement with UC elements will begin 9/63.
[10] Assumed value of turbogenerator plant. Additional charges will be required to install high pressure blades.
[11] 10 percent fixed charges, 0.8 operating factor.
[12] Average burnup 10,000 $\frac{\text{MWD}}{\text{Tonne U}}$
[13] Hallam Nuclear Power Facility estimate used as the base case. Other fuel estimates changed from ones immediately above.
[14] New steam generators for higher temperatures.
[15] For comparative reference only.

Mr. McCone. Additionally, the Commission supports this process because we believe it has promise for large plants in the future, and we take this position despite the fact that one country has recently decided to abandon development of the sodium-cooled thermal reactor and to place emphasis on other types.

To develop a process for using natural uranium fuel we will concentrate on heavy water types and will complete construction of the heavy water test reactor previously authorized for Savannah River, the plutonium recycle test reactor—which uses heavy water—previously authorized at Hanford, and the 17-megawatt electrical heavy water moderated pressure tube reactor to be built by the Carolina-Virginia Nuclear Power Associates. These projects have been well conceived and warrant continued support.

In addition we will continue to cooperate with the Canadians in the development of heavy water moderated power reactors bringing to bear the use of our special facilities along with their two heavy water natural uranium test reactors and the 20 megawatt electrical nuclear power demonstration plant which they now have under construction. Cooperative projects with Canada or other countries appear to be the best way to proceed if and when a prototype reactor becomes clearly justified.

It is my opinion now, as it has been for many years, that breeder-type plants must be developed as long-range protection against a dwindling supply of uranium for fuel. The second experimental breeder reactor, with its revolutionary pyro metallurgical reprocessing and refabrication plant as an integral part of the reactor, is under construction and will be completed in 1960. Results from this and the 100 megawatt Enrico Fermi plant will place us in a position to build future commercially useful plants of this type.

Basic research and development is to be continued on fluid fuel reactors but the experiences of our Oak Ridge Laboratory with the aqueous homogeneous reactor experiment and the conclusions of the Pennsylvania Power & Light and Westinghouse Co., with the homogeneous slurry process leads us to the conclusion that further research is necessary with these processes before additional reactor experiments or prototype should be undertaken. Adequate funds are provided in our budget for this research.

Finally, as the summary indicates, we plan to design, build, and operate a process heat reactor.

It would be my hope that as these development programs go forward, and we intend to expedite them, certain utilities will determine in their own interest that they should build commercial size plants. To the extent such plants will contribute to the technology we propose to support the plants with research and development assistance, fuel waivers, and above all to make available to them all technology which is in the public domain.

Mr. Chairman, that concludes my statement.

Senator Pastore. Mr. Chairman, may I ask one short question?

Chairman Anderson. Very well.

Senator Pastore. Are the members of the Commission unanimous on this program?

Mr. McCone. They are all here.

Chairman ANDERSON. If anybody is not in agreement, he should speak now or forever after hold his peace.

When we terminated last evening, Senator Gore was questioning the Chairman, and said to you that you have described the program for the past 5 years as good, that you have stated the program you now suggest is the same, except you propose to make it a little sweeter by capital grants. The previous program proposed to sweeten it by a buy-back of fuel elements. Will you tell us how many reactors have been constructed under the program for the past 5 years? You were about to bring out a chart when we terminated.

Senator GORE. Mr. Chairman.

Chairman ANDERSON. Senator Gore.

Senator GORE. In view of the fact that the distinguished Chairman of the Commission has now presented a specific program, I would like permission to make a brief statement to the committee which I think will save a good deal of time, rather than questioning.

Chairman ANDERSON. Without objection, you may proceed.

Representative VAN ZANDT. In the meantime will you exhibit the chart while we listen to the Senator from Oklahoma?

Chairman ANDERSON. You are a little too far west.

Representative VAN ZANDT. Pardon me, I should have said, from Tennessee.

Senator GORE. It is bad enough to have a chart put up in context of what the Senator from Tennessee is saying but it is even worse to put him in the wrong State.

Chairman ANDERSON. Senator Gore.

Senator GORE. Mr. Chairman, yesterday I expressed disappointment with the statement made by the distinguished Chairman of the Atomic Energy Commission and expressed disagreement with that statement. I would like to quote that statement with which I disagree.

> It was just 5 years ago that the Commission, with the approval and support of the Joint Committee, launched the first formal civilian nuclear power program. I believe that efforts during the past 5 years have paid off in remarkable progress. I believe we have had a good program, both in terms of technical progress and in terms of participation and cooperation of industry.

I submit, Mr. Chairman, that one has only to look at the record to see what we were being promised 2 and 3 years ago, and what has happened to those promises. Let us look briefly at the record and see if they have in fact paid off in remarkable progress and whether or not we have had a good program in terms of technical progress and in terms of participation and cooperation of industry. Three years ago in public hearings similar to the ones being held today on the development, growth, and state of the atomic energy industry, the Atomic Energy Commission submitted a chart to demonstrate its planned civilian atomic power program. That chart can be found on page 28 and also on page 341 of the section 202 hearings for 1956.

I would like to submit for the record at this point, Mr. Chairman, a list of projects under the power demonstration program, and under the industrial program, and the dates they were scheduled for operation as taken from that chart, and then compare them with their current status.

Chairman ANDERSON. Without objection it is so ordered.

(The information referred to follows:)

Projects under the power demonstration program and independent industrial program

Project	Capacity and date of operation per 1956 AEC plans	Capacity and date of operation per 1959 AEC plans
Rowe, Mass., pressurized water reactor, Yankee Atomic Electric Co.	1959 (134,000 kilowatts)	1960 (134,000 kilowatts).
Monroe, Mich., fast breeder reactor, Power Reactor Development Co., Inc. (Detroit Edison Co. and others).	1960 (100,000 kilowatts)	1960 (90,000 kilowatts).
Nebraska, Sodium graphite reactor, Consumers Public Power District.	1959 (75,000 kilowatts)	(Deferred.)
Elk River, Minn., boiling water reactor, Rural Cooperative Power Association.	1960 (22,000 kilowatts)	1961 (22,000 kilowatts).
Gainesville, Fla., pressurized water reactor, University of Florida.	1959 (2,000 kilowatts)	Canceled.
Piqua, Ohio, organic moderated reactor, City of Piqua.	1960 (12,500 kilowatts)	1961 (10,500 kilowatts).
Hersey, Mich., aqueous homogeneous reactor, Wolverine Electric Cooperative.	Unknown (10,000 kilowatts).	Canceled.
Anchorage, Alaska, sodium cooled-heavy water moderated, Chugach Electrical Association, Inc., Nuclear Development Corp. of America.	1961 (10,000 kilowatts)	Do.
Orlando, Fla., liquid metal fueled reactor, city of Orlando.	1960 (25,000 to 40,000 kilowatts).	Do.
Holyoke, Mass., gas cooled reactor, city of Holyoke.	Unknown (15,000 kilowatts).	Do.
Indian Point, N.Y., pressurized water reactor, Consolidated Edison Co.	1960 (150,000 kilowatts)	1960 (255,000 kilowatts).[1]
Dresden, Ill., boiling water reactor, Commonwealth Edison Co.	1960 (180,000 kilowatts)	1959 (180,000 kilowatts).
Eastern Pennsylvania, aqueous homogeneous reactor, Pennsylvania Power & Light Co.	1962 (150,000 kilowatts)	Canceled.

[1] Including over 100,000 kilowatts from conventional fuel.

Senator GORE. Of 13 power projects then presented to us, most of which were to be completed in the period 1959–62, 6 have been canceled and 1 indefinitely deferred. Those that were canceled during the past 3 years were a 2,000-kilowatt reactor at Gainesville, Fla., originally scheduled for operation in 1959. A 25,000 to 40,000-kilowatt reactor at Orlando, originally scheduled for operation in 1960. A 150,000-kilowatt reactor by the Pennsylvania Power & Light Co., originally scheduled for operation in 1962. A 10,000-kilowatt reactor by Chugach Electric Associates of Anchorage, Alaska, originally scheduled for operation in 1961, the cancellation of which we were notified about yesterday. A 15,000-kilowatt reactor, Holyoke, Mass., and a 10,000-kilowatt reactor to be constructed by the Wolverine Electric Cooperative at Hershey, Mich. The latter two projects, even in 1956, did not have any scheduled date for operation, yet were listed by the Commission at that time to support what purported to be at that time the Commission's "wonderful program."

Another project—a 75,000-kilowatt reactor by Consumers Public Power District in Nebraska was scheduled for operation in 1959. On yesterday the Joint Committee was informed that construction was to

be deferred on this project for another 2 years. It could not come into operation, therefore, until about 1964 with cancellation possible, if not probable, before then.

As I see it, this does not represent a remarkable program and a record of remarkable progress. I sincerely hope, however, that 3 years from now the program which is being presented today, and the projects now reported to us as planned, will stand up better than those that were presented to us during the past 5 years.

Now, with respect to the specific program which has just been presented, to the uninitiated, the reading or the hearing of this specific plan would sound as if no stone had been left unturned. Yet we were told yesterday that it was essentially the same program that was presented by the Commission in 1956, with two differences:

One, the Commission now proposes to give money directly to the power concerns to build the plants. Second, there is no time limit fixed during which the Commission would wait for satisfactory proposals before acting itself.

The staff has supplied to members of the committee an analysis of the actual proposed authorization bill which the Commission has submitted. I would like to compare that bill, that proposal, with what the Congress authorized last year, and which the Commission said it could perform. When thus compared, I believe the record will show that the present program is more timid and requests a cutback as compared with the program agreed upon by the committee and the Commission last year.

If the committee will refer to section 107 of the draft of the proposed authorization bill, which I understand is now before each member—on page 6, you will find that a cutback is proposed. Last year there was a total for direct AEC program of $74,550,000. When you take from the present program or the program presently presented, the cancellation in section 107, you find a net total for the next fiscal year of only $14,500,000, compared with the $74,550,000 a year ago.

Then in the cooperative program, the program of cooperation with industry, last year the program agreed upon by the Commission and which this committee authorized, amounted to $25,188,000. Members of the committee, if they will turn to section 113 of the proposed bill of authorization, you will find again a cancellation of $20 million, which represents a net minus $500,000. Let me restate the figures. A year ago it was $25,198,000. This year the recommendation is $19,500,000, but from which is subtracted $20 million, leaving a minus $500,000.

Mr. Chairman, I would like to submit this for the record, a chart compiled by the staff of the committee.

Chairman ANDERSON. Without objection, it is so ordered.

(The chart referred to follows:)

Civilian power program—Comparison of funds authorized by fiscal year 1959 Authorization Act (Public Law 85–590) with funds requested by AEC proposed authorization bill for fiscal year 1960

PUBLIC LAW 85–590 (FISCAL YEAR 1959)

AEC PROGRAM

59–d–7	Modifications to OMRE, EBWR, BORAX	$6,300,000
59–d–8	Heavy water component test reactor	8,000,000
59–d–10	Gas-cooled power reactor	[1] 51,000,000
59–d–12	Design study—heavy water	2,500,000
59–d–13	Design studies—3 reactors	6,000,000
59–d–14	Design study—nuclear superheat	750,000
	Total	[1] 74,550,000

COOPERATIVE PROGRAM

Sec. 109	Increase in cooperative program	[1] $25,198,000

AEC PROPOSED BILL FOR FISCAL YEAR 1960

AEC PROGRAM

Sec. 101(e)	Modifications to EBR–1	$1,000,000
Sec. 101(e)	Portable gas-cooled	2,500,000
Sec. 101(e)	Modifications to MTR–ETR	2,000,000
Sec. 107(a)	Flexible experimental gas-cooled	30,000,000
Sec. 110	4 experimental and prototype	[2] 30,000,000
	Total	65,500,000
Minus sec. 107(a)	Striking 59–d–10	51,000,000
	Total	[1] 14,500,000

COOPERATIVE PROGRAM

Sec. 111	R. & D. assistance	$5,000,000
Sec. 112	Advanced high-temperature, gas-cooled	14,500,000
	Total	[2] 19,500,000
Minus sec. 113	Decrease in cooperative program	−20,000,000
	Total	−500,000

[1] 59–d–10 alternatively available for AEC construction or cooperative program under sec. 110 of Public Law 85–590.

[2] $30,000,000 for experimental and prototype power reactors is for construction "either in cooperation with industry or by direct Government contract" under sec. 110 of proposed bill.

Senator HICKENLOOPER. Would the Senator from Tennessee make it a little more clear? I am looking at section 13, and I cannot find it.

Senator GORE. Section 113. I will read it.

Section 1096, Public Law 85–590 is amended by striking out the figures "$155,113,000" and "$175,113,000" and inserting in lieu thereof the figures "$135,113,000" and "$155,113,000," and by striking out the figure "$2,750,000," and inserting in lieu thereof the figure "$4,309,000."

If the Senator will make his calculations, he will see that the bill represents a minus $500,000 when the authorization requested this year is compared with the authorization enacted last year.

Mr. Chairman, I would like to submit for the record another table comparing the prototype and experimental reactor the AEC now pro-

poses for fiscal year 1960 and what was proposed for fiscal year 1960 by the Commission last year.

Senator ANDERSON. It is so ordered.

(The table is as follows:)

AEC CIVILIAN REACTOR DESIGN AND CONSTRUCTION PROGRAMS COMPARISON OF AEC OFFICIAL STATEMENTS IN 1958 AND 1959

Prototype and experimental reactors proposed for fiscal year 1960 in hearings on atomic power program in May–June 1958 (AEC authorization hearings—85th Cong., 2d sess., pp. 273–279).	Proposed reactor prototypes and experiments as set out in Chairman McCone's February 17, 1959, statement for February 1959 "202" hearings and authorization proposal.
I. Prototypes:	I. Prototypes:
1. Heavy water moderated power reactor (100,000 KWE[1]).	1. Not included.
2. Single region aqueous homogeneous reactor of large scale. Penn. Power & Light (100,000 KWE[1]).	2. Canceled.
3. Small scale pressurized water (20,000–40,000 KWE[1]).	3. Not included.
4. Heavy water moderated gas-cooled prototype reactor (east coast of Florida (50,000 KWE[1]).	4. Included—has been authorized. No contract signed as yet.
5. Heavy water moderated and cooled prototype reactor (Carolinas – Virginia) (17,000 KWE[1]).	5. Included—authorized and contract signed.
6. Heavy water moderated, sodium cooled experimental plant (Chugach) (17,000 KWE[1]).	6. Canceled.
7. Process heat prototype reactor.	7. Included.
8. Gas-cooled prototype (40,000 KWE[1]).	8. Canceled gas-cooled prototype power reactor.
	9. Advanced boiling water prototype.
	10. Advanced high temperature, gas-cooled reactor (PE–GD).
	11. Small nuclear powerplant (20,000 KWE[1]).
	12. Delayed Hallam sodium cooled reactor—Consumers Public Power of Nebraska (75,000 KWE[1]).
II. Reactor experiments:	II. Reactor experiments:
1. Organic moderated reactor experiment.	1. Included.
2. Intermediate sized 2-region aqueous homogeneous reactor experiment (design).	2. Not included.
3. Molten salt experimental reactor.	3. Not included.
	4. Borax V (40,000 KWT[2]).
	5. Experimental sodium cooled reactor (design).
	6. Flexible experimental gas-cooled reactor.
	7. Canceled liquid metal fueled reactor experiment.

[1] KWE—kilowatts of electrical power.
[2] KWT—kilowatts of thermal power.

Senator GORE. Mr. Chairman, yesterday the distinguished chairman, for whom I have a warm affection and with whom I enjoy a most agreeable personal acquaintance, stated that one of our objectives was to maintain U.S. leadership in the field of nuclear power.

Chairman ANDERSON. Is there any objection to insertion of these items in the record? The Chair hears none, and it is so ordered.

Mr. MCCONE. Mr. Chairman, could I just ask for the privilege of checking these figures?

Chairman ANDERSON. Yes.

Mr. MCCONE. I have not seen them.

Chairman ANDERSON. There is no objection to getting copies of them.

Mr. MCCONE. It takes a little checking.

Senator GORE. It was going to be my suggestion that instead of a long exchange between us to cover this material which would probably take maybe an hour and a half, that I submit this statement, and that if you should desire to defer comment on it until tomorrow, it would be satisfactory. I had no intention whatever to use statements or analyses with which you are not familiar.

Chairman ANDERSON. Would the Senator allow the Chairman to comment now as he wishes?

Representative VAN ZANDT. Has a copy of the statement been submitted to the press?

Senator GORE. It has not.

Mr. MCCONE. I would like to say this——

Chairman ANDERSON. If you will yield Congressman Hosmer.

Representative HOSMER. I would like permission to make a short statement, too, in relation to these figures, because I think they are a little difficult to prove anything from.

Chairman ANDERSON. Let Senator Gore complete his statement.

Representative HOSMER. Excuse me.

Mr. MCCONE. Mr. Chairman, could I just inject one thing here.

Chairman ANDERSON. I am going to go ahead, Mr. McCone, and let you make a statement because I think you should. You can see what I will be into shortly if I don't try to hold some order. You go ahead, Mr. McCone.

Mr. MCCONE. I just want to say that I asked for information as to the total expenditures for operating expenses, plant acquisition, and construction and experimental and prototype reactor program of the civilian power program. These are the Atomic Energy Commission actual dollar expenditures. In 1958, $130,354,000. In fiscal year 1959, estimated, $182,343,000. In fiscal 1960, estimated, $249,110,000.

Senator GORE. You understand, Mr. Chairman, that the comparison I was making was between the program authorized by Congress last year, and which the Commission said it could do on the one hand, and the program presented by the Commission today. I was not referring to accumulated expenditures as existing projects are constructed. I was comparing a year ago with now from the standpoint of authorization.

Representative VAN ZANDT. Will the gentleman yield at this point?

Senator GORE. Yes.

Representative VAN ZANDT. Is it not true that some of the differential you point out is represented by cancellation of the Pennsylvania Power & Light Co. project for which $7 million was appropriated? The cancellation of this contract was not the work of the Commission. It was on the initiative of the manufacturer and the utility.

Senator GORE. Mr. Chairman, if I might conclude.

Chairman ANDERSON. Will you complete your statement?

Senator GORE. One other statement which the distinguished Chairman made yesterday was that the aim of the program was to maintain U.S. leadership in this field of nuclear power. In that connection, I would like to read a story appearing in the New York Times on January 23, 1959, dateline Moscow:

Two new atomic powerplants are under construction in the Soviet Union and two others are being prepared for chosen sites, a Soviet official disclosed today.

Departing from the reading of the article, the members of the committee will know that this committee in executive session had information with respect to the two plants herein referred to more than a year ago.

G. V. Yermakov, chief engineer of the atomic power administration in the Ministry of Electric Power Station Construction, told the newspaper Trud that plants were going up in the Ural Mountain area and in the Voronezh region, about 300 miles south of Moscow.

The Ural plant, the Soviet Union's third, will have a uranium-graphite reactor capable of producing superheated steam. The installation's efficiency was said to be 37 percent, which would be greater than that of the Soviet second plant.

The second station, work on which followed construction of a 5,000-kilowatt experimental plant, was put into operation last September. Its first section has a capacity of 100,000 kilowatts. When completed it will have a capacity of 600,000 kilowatts. Its location is considered a secret here.

The fourth station at Voronezh, was said to be designed for a capacity of 420,000 kilowatts.

Again diverting from the article, while in the Soviet Union some 15 months ago I was told personally of a plant being constructed in the order of 450,000 kilowatts. I was not told of the location.

A fifth plant is scheduled to be built in the Leningrad region and a sixth somewhere on the Volga River.

In view of the progress in Great Britain of which we have detailed knowledge and in view of the admittedly less accurate information which we have about progress in the Soviet Union, the United States must take care lest it become a poor third in the construction and operation of large-scale nuclear powerplants, if indeed it is not already third.

Thank you, Mr. Chairman. I request that the Chairman have ample opportunity to review the statistics that I have submitted for the record and to reply as he chooses.

Chairman ANDERSON. I had agreed to recognize Mr. Hosmer. Mr. Van Zandt is the ranking minority member on the House side and I will recognize Mr. Van Zandt.

Representative VAN ZANDT. Mr. Chairman, since we are involved in a discussion of who is ahead and who is behind in the atomic power

field, it might be of interest at this point to read an article here from the New York Times, in which it says:

The Atomic Industrial Forum, the National Industry Association, reported completion of a total of 37 nuclear reactors of all sorts and for all uses in the United States and abroad during the year. The Second International Conference on Peaceful Uses of Atomic Energy, Geneva, last September, opened on the realistic report that 17 years after the dawn of the nuclear age, the nations of the world have installed a capacity of only 200,000 kilowatts of atomic capacity, enough to power a city of 200,000 persons.

The article continues:

Program called sound. On a more optimistic note the Mid-American Assembly at the University of Missouri—

and I understand it was a very representative group—

last September issued the following appraisal of the industry: "The U.S. program is generally sound and probably more advanced than that of any other nation. Of the many additional good things which may be said for the special mentions made of the diversity of the reactor types being investigated, concern for safety and the encouraging amount of industrial participation using private funds."

Representative HOSMER. If the gentleman will yield.

Representative VAN ZANDT. It is a pleasure to yield.

Mr. HOSMER. I think it was a risky conclusion that the gentleman from Tennessee drew from the numerological acrobatics of the sheet comparing last year's program and this year's. We ought to realize that the $51 million for the gas reactor as added to the 1959 fiscal picture, and then subtracted from the 1960 picture, naturally presents a dramatic difference. If we assume, which we logically must, that that type reactor program was in reality shifted a year in programing, we bring down the actual comparison to reality. The actual comparison in money of the 1959 program with the 1960, eliminating the $51 million for the gas-cooled reactor is, for 1959, $23,550,000, and for this 1960 request, $65,500,000.

Chairman ANDERSON. You put back in the $30 million for the gas cooled.

Representative HOSMER. That is where it belongs because it is going to be done this year. Let us take then what hardware was going to be bought last year in the 1959 request. There were three modifications of reactors, one test reactor and five design studies. Mr. McCone is asking for this 1960 year for two modifications and six reactors, a considerably favorable increase.

If we can believe his 25th semiannual report and the listing that starts on page 266, of reactors which have been built, we will have to take the year 1955 as the breakoff point between him and his prede-

cessor, and his predecessor's predecessor, giving about 3 years for reactor construction. For 1955 and earlier, including all types of reactors, including general test reactors, research and training reactors for the United States and export, we find in 1955 and earlier there were 23 reactors. For 1956–59, that is this year, built, and, to be finished this year, 97 reactors. For 1960 and beyond, in building, 31. That is a total for Mr. Strauss and Mr. McCone of 138 reactors as against 23 for their predecessors. If this were a basketball game that would be a pretty decisive score. I only make these remarks because of those that were made by the previous member of the committee.

Senator GORE. Will the gentleman yield?

Representative HOSMER. In just a moment. I want to say that for this 1956 and on period, the total amount of electric kilowatts in the United States amounts to 1,239,450, and for U.S. export reactors, 331,000, a total of 1,560,450 electric kilowatts. A substantial total, and I think a total in which each of the members of this Commission can take great pride. Somebody wanted me to yield. I yield.

Representative VAN ZANDT. I yield to the Senator from Tennessee.

Senator GORE. The distinguished Representative from California said that if we could believe the accuracy of the chart on page 266, we would come to certain conclusions. If he will notice that table lists the Hallam nuclear power facility, the cancellation of which we have just been notified about today.

Chairman ANDERSON. No; it has been delayed.

Senator GORE. Delayed instead of canceled. It is listed as being built on page 266 in that table which the distinguished Congressman referred to.

Representative HOSMER. Will the gentleman yield?

Senator GORE. Yes.

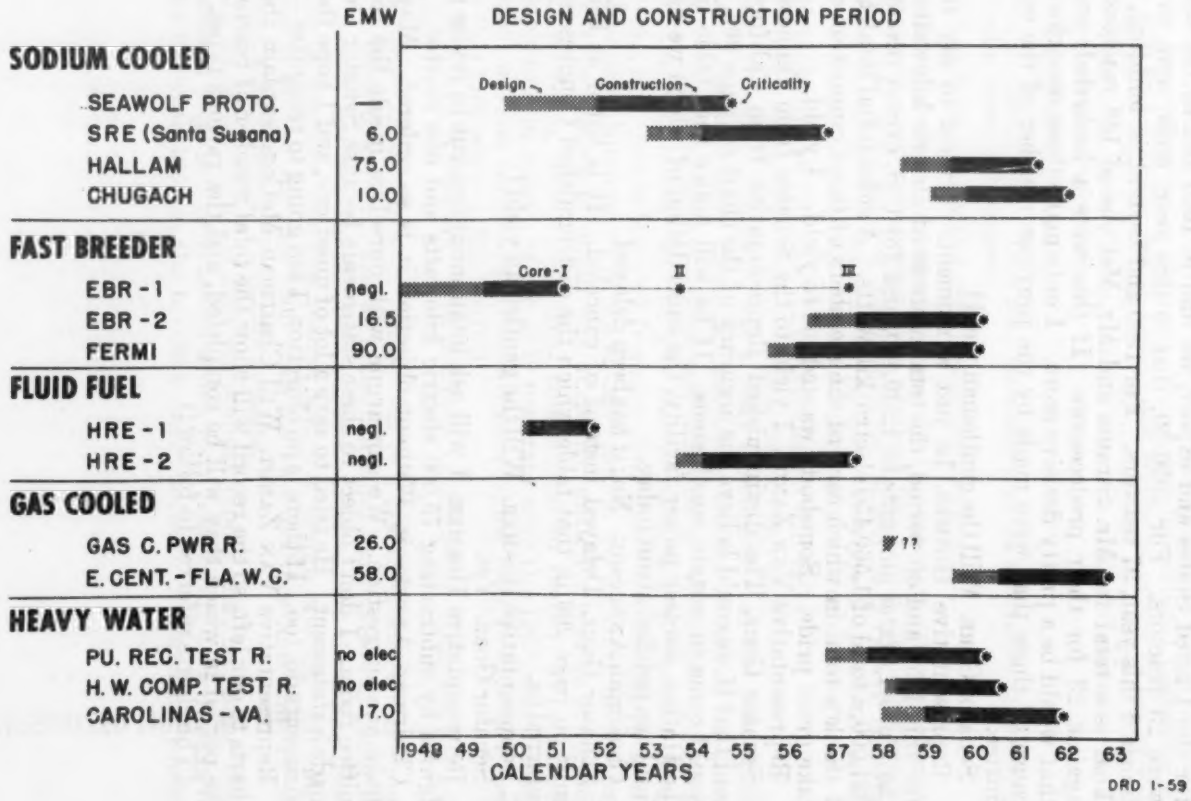
Representative HOSMER. I will ask unanimous consent to revise my figures by subtracting 75,000 electric kilowatts and one reactor.

Chairman ANDERSON. Without objection it is so ordered. May I make one suggestion. We can argue with ourselves inside the committee room. I don't object to these statements because Senator Gore made a statement. He tried to save a lot of questions, and I hope these comments do, too. If there is no objection, I am going to recognize——

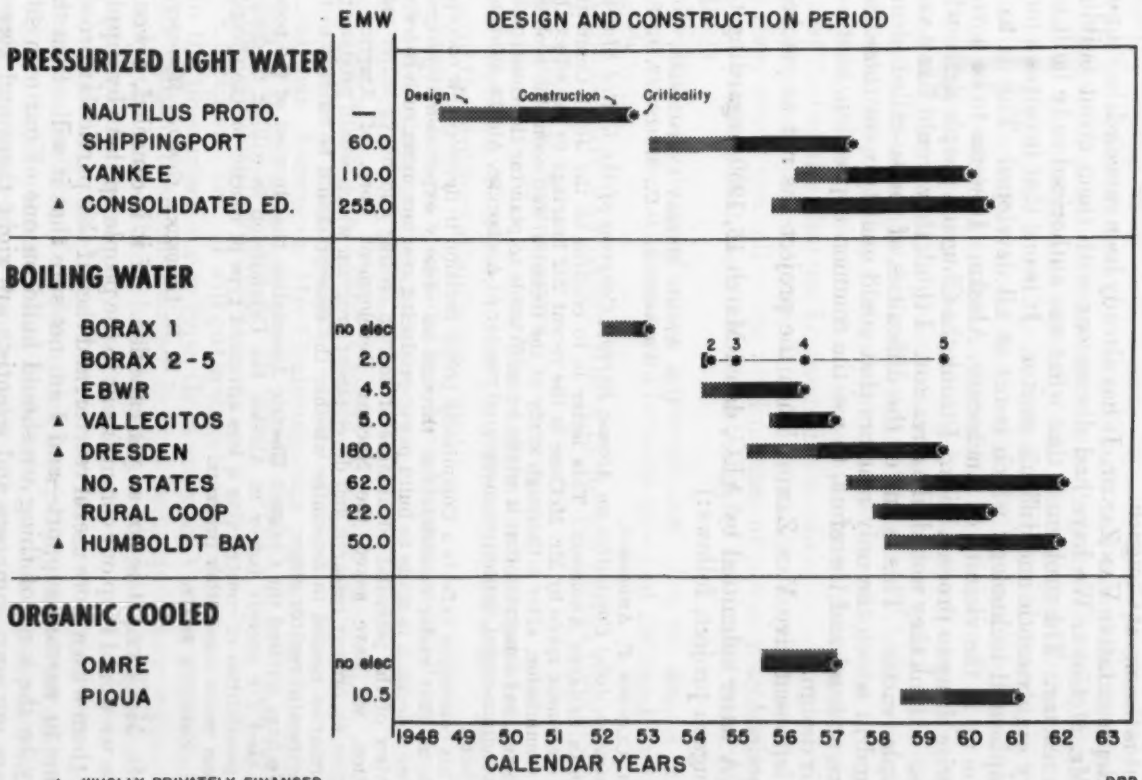
Representative VAN ZANDT. Will Chairman McCone explain these charts to our left, so the record will show the total number of reactors, the period in which they will be completed, and the various types.

(The charts referred to follow:)

STEPS IN POWER REACTOR DEVELOPMENT



STEPS IN POWER REACTOR DEVELOPMENT



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DRD 1-59

Mr. McCone. These are all of the reactors which have been authorized by the committee. This does not include the several reactors, six or seven, which are in our recommendations. It is broken down as to types. While I am rather confused as to the numbers that have been going on here, I only know of one reactor previously authorized which has come to my attention, which I am suggesting that it not be built. That is the one at Chugach.

Representative Van Zandt. It has already been canceled, has it not?

Mr. McCone. We have had discussions with them about building the reactor. The problem is that what was authorized to be built is a very highly exotic and difficult reactor. It is one that involves a most complicated technology which is not at all developed This is to be done up in the vicinity of Anchorage, Alaska. It seems to be a very unwise thing to proceed with. I think the Chugach people agree with this. I think they would like a reactor. I think they would like a very simple reactor. This is one of the difficulties of the so-called second round in which the only reactors that could qualify were those that were unusual and therefore, to use the common expression, exotic in their design.

Representative Van Zandt. Then the project has not as yet been canceled?

(A letter submitted by AEC, dated March 13, 1959, regarding the Chugach project, follows:)

U.S. Atomic Energy Commission,
Washington, D.C., March 13, 1959.

Hon. Clinton P. Anderson,
Chairman, Joint Committee on Atomic Energy, Congress of the United States

Dear Senator Anderson: This letter is to confirm to the Joint Committee the statement made by Mr. McCone in the recent 202 hearings to the effect that the Commission, after a thorough study of the technical and economic problems involved, has concluded that it would be inadvisable to plan for the construction of a sodium-cooled, deuterium-moderated reactor at Anchorage, Alaska (Chugach project).

This conclusion reflects a Commission policy decision to develop new concepts, such as that under consideration, through an orderly experimental program before a decision is made to build power-producing reactors using such concepts. In view of the potential advantages of sodium cooling and heavy water moderation, we have asked the Nuclear Development Corp. of America to suggest an orderly research and development program which would produce the information needed to determine whether the concept should be carried to the experimental reactor stage.

We have advised the Chugach Electric Association that in view of the potential need for nuclear power in Alaska, the Commission is willing to discuss the possibilities of constructing a less advanced type of reactor on the Chugach system under some other program.

Sincerely yours,

A. R. Luedecke, *General Manager.*

Mr. McCone. It is not as yet canceled. If it is canceled, I would hope we would keep our commitment to the people up there by supplying them with a more useful reactor, and then if this particular process seems to warrant support—and I am not sure that it will—then this may be the kind of thing we should build on one of our own sites where our own engineers and scientists are right there and keep it going and they don't all have to fly up to Alaska to keep the reactor in operation. That is why I have very strongly urged that the Chugach people recognize the problem that has been made for them.

Here is the Shippingport reactor which, as you know, has been constructed and is in operation. Here is the Yankee reactor and the Consolidated Edison reactor, both of which are under construction, both of which will be completed in 1961. These dates have been confirmed. We think that the work is progressing satisfactorily.

I have talked personally to the presidents of both companies.

In the boiling water field, I have explained the program on the Borax No. 5, and that reactor is to be built and completed in 1 year. The experimental boiling water reactor at Argonne has been in operation. It has operated successfully. It has operated at three times its design criteria. It will be modified this year to operate at five times its power criteria, and this work will be completed and this reactor put back in operation in December of this year.

The Vallecitos reactor was privately built by the General Electric Co. It will interest this group to know that this reactor, which is 7,500 kilowatts electrical, but could be much larger, was built in exactly 13 months from the time that ground was broken until it was brought to criticality, and it was built in 15 months only from the day they started the first drawing until it reached criticality.

Representative VAN ZANDT. Mr. Chairman, for the purpose of saving time, would you tell us the total number of power reactor development projects that have come into being for the period from 1960 to 1962?

Mr. MCCONE. They all come in except one. Let me see. I will have to count them. There are 13 between now and 1962 and 1 more in early 1963.

Representative VAN ZANDT. About 14 for the period from 1959 to 1963.

Mr. MCCONE. That is correct.

Representative VAN ZANDT. What are the various types of reactors?

Mr. MCCONE. There are seven. I did not count the fluid fuel because of the problems attendant therewith.

Representative VAN ZANDT. You have 14 reactors in all representing 7 different types of reactors.

Mr. MCCONE. That is correct.

Representative VAN ZANDT. Coming in for the period 1960 to 1963.

Mr. MCCONE. That is correct.

Chairman ANDERSON. Mr. Chairman, you pointed for the record what you indicated would not be visible. Will you call them off so that the record will show them?

Mr. MCCONE. Yes. I will go through them briefly.

In the pressurized water type, there are two, Yankee and Consolidated Edison, the Consolidated Edison being privately supported entirely, the Yankee being built by private capital and supported in research and development by the Commission.

In the boiling-water type there is the Borax V which will be a Commission facility. Dresden, which is privately supported and privately built. Northern States, built with private funds, but with Commission research and development. There is the Rural Cooperative at Elk River in which the Commission is putting up the money for the reactor. There is Humboldt Bay, privately financed, with no Commission support.

In the organic cooled, there is Piqua, in which the Commission is providing the reactor and the city of Piqua the power equipment.

In the sodium cooled, as I mentioned, Chugach, we are contemplating cancellation. Hallam we are discussing delaying. That was not included in the 14. In the fast breeder there is EBR 2 which is Commission built. There is the Enrico Fermi plant, which is privately built, research and development supported by the Commission.

In the gas cooled, there is the proposed gas cooled test reactor to be built by the Commission with the possible supplying of the generating equipment by industry. That has not been negotiated. If not, the Commission will supply it.

There is the east central Florida-west coast projects which is privately financed, but research and development supported by the Commission. In addition, there is the Philadelphia Electric proposal which is not included in the count.

In the heavy water, there is the plutonium recycle test reactor, Commission built, the heavy water components test reactor, Commission built, and there is the Carolina and Virginia small power generator which was built by private finance, but with Commission support of research and development.

Senator PASTORE. Mr. Chairman, may I ask a question?

Chairman ANDERSON. Mr. Van Zandt has the floor.

Senator PASTORE. Will Mr. Van Zandt yield for a question?

Representative VAN ZANDT. It will be a pleasure.

Senator PASTORE. Mr. Chairman, what is basically the American policy by way of comparison with Great Britain and Russia with relation to the development and formulation of our own civilian power reactor program? We have heard from time to time that English are doing this, the Russians are doing that, we are doing so much. Basically what is our governmental policy in relation to the civilian reactor program.

Mr. MCCONE. Let me speak first about the British and our comparison with the British, because I have heard a great deal said about the British program. I think any country that has any knowledge in this nuclear field has to more or less tailor its power program to meet its domestic and internal requirements. In Britain they have had two problems. First, they had very high cost conventional power, which came from either expensive coal or imported oil, and in the case of the latter it was not only high in cost but a drain on their dollar reserves.

Secondly, they had a need for plutonium. So they proceeded with the building of a low temperature natural uranium gas cooled reactor. They had to go to natural uranium because they had no gaseous diffusion plant at that time, and therefore they had no U^{235} to partially enrich their fuel. They have been successful in producing and developing a plant which produces electricity and it also produces a substantial amount of plutonium. It is not cheap plutonium and it is not cheap electricity, but it serves their purpose. They have several, or four such plants in operation at the present time that generate a total of 140,000 megawatts of electricity, and that is all. They have several biulding, and over the next 2 or 3 years they will bring in several hundred thousand kilowatts of electricity from plants of this

type. This is the design of a plant that was considered at the Argonne before we built the Hanford reactor and it was rejected as being uneconomical.

After I went to Britain in November, I made a very intense study as to whether our additional plutonium requirements, which were to be produced in the new production reactor that you authorized last year and is now being designed to go at Hanford, that that plutonium might not better be produced in a gas-cooled reactor. We get some electricity out of it. Despite the fact that we studied it in every possible way, we could not reach the conclusion that this held any promise to the United States in the light of our power economy, and our cost of power, and the very low cost of plutonium, comparatively, in our Hanford plants. We therefore rejected this as a possibility.

As the British are getting product from their gaseous diffusion plant, they are moving away from this process and they are moving into a slightly enriched, higher temperature type of plant, very similar to the Kaiser-ACF plant that has been designed and was authorized and which I propose to build. This is going to give them a little lower cost power and less plutonium, but they are coming into a little different balance.

There are now and have just been completed joint arrangements with the OEEC countries to build an experimental high temperature plant similar to the Philadelphia Electric proposal, although it will be a smaller plant, and this, they hope, will carry them into another step of still more economical power. This is longer range. This interests me and this is why we have made the proposal that we have made to go forward with these two gas cooled reactors.

They are doing active work in another field and that is the fast breeder. They have built and experimental reactor at Dounreay. I have inspected it as has Dr. Libby. It is a very advanced and very fine reactor. It will be in operation some time this year. It will compare with the EBR 1 and EBR 2. They are exchanging information with us on this design and they are exchanging information with the Enrico Fermi people.

We are more advanced in this field than they are, although they have built a very fine plant up there at some considerable cost. I feel that they have done a very good job in gas-cooled reactors. It was the type of development that does not fit into our economy. Their first plants, the ones that have just been completed, cost in Britain $600 per kilowatt. I would think it would cost $1,000 a kilowatt here. I do not think those plants would produce power for less than 25 mills in this country. That is why I feel that we have not lost ground to the British, despite the fact that because of their particular economic conditions, and the fact that nuclear power is indigenous within their country, and they had high power costs they could approach the problem differently than we have.

As regards the Russian situation, I have heard many reports, and I read the article that Senator Gore read. I am a little confused about just where the Russians stand. Yesterday the chairman asked me what my views were on Russia. I told him all I knew. He had a letter from Dr. Zinn, I believe. He said my views rather coincided with his. This is all I know. This is a mystery and all we can do is guess. Mikoyan said that they were approaching this very deliber-

ately. Emelyanov told me—he is the head of the Atomic Energy Commission over there—he is proceeding with four 50 megawatt prototypes of different systems and one 35 megawatt. He said he would send me a paper describing them, but he did not do it.

Senator ANDERSON. I think, Mr. Chairman, I should say that I did say Dr. Zinn's views agreed with a great many of yours. I think Dr. Zinn feels the Russians are a little more aggressive than perhaps you have indicated. I do, however, think the two views are very similar.

Mr. MCCONE. I do not want to give you the impression that I feel that the Soviets are not aggressive in this field. I think they are aggressive and I think they are capable. This plant that they talked about, this 100,000 megawatt plant, and the four others that I believe are referred to in that article, are definitely in our opinion plutonium producers. This I think we are sure of.

Senator PASTORE. But you have not answered my question. My question is, what is basically our policy? Are we interested in maintaining supremacy? When we formulate and advance these programs, just as you have now, which I applaud, do we have as one of the considerations—one of the prime considerations—in mind the progress that is being made by other countries. Are we interested in whether we maintain our own supremacy, or are we concerned with the available supply of electric current in this country as to whether we need it, whether we need to go at any accelerated speed? What is definitely our policy in the formulation of this program? Do we mean to outdistance the British? Do we mean to outdistance the Russians? Don't we care whether we do, or are we interested alone in auxiliary power? I would like to know here as succinctly as we can find out exactly what is the underlying policy of the U.S. Government with reference to civilian reactor development.

Mr. MCCONE. I think this, Senator Pastore. In our own self-interest, and irrespective of whether it is being done by any other country in their own self-interest, I think we must place a very great emphasis on the development of nuclear power, because I feel that we need nuclear power in many areas of this country at this time, and we will need it in increasing amounts in the future as our power demand grows and as the availability of fossil fuels becomes more and more scarce. That is my view. I was extremely interested in sitting down with the heads of many of the large power companies, most of whom are represented in these various groups, and have them say that they thought that was one of the primary reasons why we must lay

special emphasis on this program and why they are putting substantial amounts of their own stockholders' money in the program.

Secondly, I feel that to advance this technology, to have these plants, to have them for export where they will be of value to friendly countries, is a useful instrument of our foreign policy. However, I do not think this is the type of thing in which I think a so-called kilowatt race is of particular importance.

Senator PASTORE. Then is it fair for me to assume that basically it is our policy that whether or not we have any immediate need for this power that is within the next 5 or 10 years, we have every determination to go forward with full acceleration in this program, and that we are also taking into account the progress that is being made by other countries in order that we may maintain international superiority for the propaganda values that may be involved?

Mr. MCCONE. I think that is a good summary, sir, of our situation. I think the term "full acceleration" is rather hard to define, because of the very difficult interrelationship between necessary and essential scientific developments and the actual building of plant. I think that this program represents a very aggressive and forward looking program in this field and it will bring results.

Senator PASTORE. The reason I asked the question, is that shortly after we amended the law in 1954, one of the very distinguished leaders in the private power field took occasion to say before this committee that after all, we didn't have the same need for this power as other countries did. He stated that we had an abundance of fossil fuels in the United States of America, and at best this would only serve an auxiliary purpose. I am glad to hear you say that is no longer a consideration in our policy.

Mr. MCCONE. That is true, sir.

Representative VAN ZANDT. Mr. Chairman, can you furnish us the amount of money we have put into the pressurized light water type reactor?

Mr. MCCONE. I will have to get my notes.

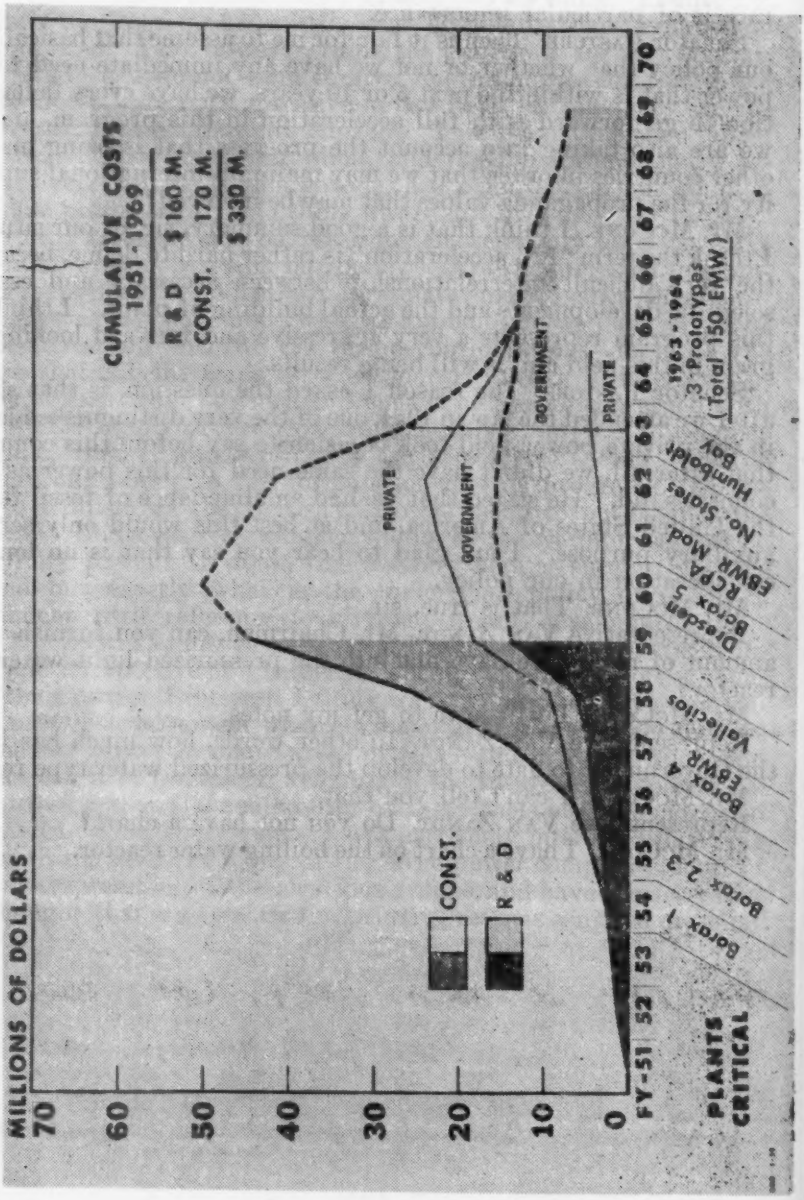
Representative VAN ZANDT. In other words, how much has it cost the Government to date to develop the pressurized water type reactor.

Mr. MCCONE. I can't tell you that.

Representative VAN ZANDT. Do you not have a chart?

Mr. MCCONE. I have a chart on the boiling water reactor.

(The chart referred to follows:)



Representative VAN ZANDT. Mr. Chairman, then give the committee what we have spent to date in developing the boiling water reactor.

Mr. MCCONE. This is boiling water and does not include any military reactors at all. This represents a 14-year program. This is the curve of expenditure. This represents expenditures for construction and for research and development and they are actual to this point in mid-1959, and this is the forecast [pointing to chart]. This represents expenditures by both Government and by private industry, as near as we can estimate.

I call your attention to the figure of $330 million, and that is after crediting against the cost the equivalent conventional cost of such power generation as resulted.

Representative VAN ZANDT. Now, do I understand the development of the boiling-water-type reactor has cost $330 million to date?

Mr. MCCONE. Not to date. It will cost $330 million by the time we get to a point where we can consider that boiling water will be reasonably competitive or power from boiling water will be reasonably competitive.

Representative VAN ZANDT. In 1969?

Mr. MCCONE. No; it will come earlier than that. I think that figure runs out to 1965.

Chairman ANDERSON. When the Government gets out.

Mr. MCCONE. That is right; 1965.

Representative VAN ZANDT. That is all, Mr. Chairman.

Chairman ANDERSON. Senator Gore has a brief question or two and then we will start with other members of the committee.

Senator GORE. Mr. Chairman, I wish to read into the record some statistics compiled by the committee staff.

This compilation shows that Great Britain has 1,695,000 kilowatts of capacity, either completed or on which construction has begun. I would like to read the plants:

Calder Hall, 150,000 kilowatts, in operation.

Chapel Cross, 150,000 kilowatts, in partial operation.

Berkley, 275,000 kilowatts, construction started January 1957, first unit to be completed in December 1960.

Bradwell, 300,000 kilowatts, construction started in January 1957, expected to be completed December 1960.

Hunterston, 320,000 kilowatts, construction started in October 1957.

Hinkley Point, 500,000 kilowatts, construction on which started December 1957.

In addition to these projects, either already completed and in operation, or on which construction has been underway since varying times in 1957, there are three more plants scheduled: Two of 500,000 and one of 650,000 kilowatts, making a total capacity, in operation, under construction, and planned, of 3,345,000 kilowatts.

Senator BENNETT. Will the Senator yield?

Does the staff study show the average cost of those kilowatts?

Senator GORE. This particular one does not. I am sure the staff would be glad to supply the able Senator whatever information it has on that point.

Chairman ANDERSON. I doubt if the staff can, because it depends on what price you put on plutonium.

Mr. McCONE. Mr. Chairman, I think this information that was given to Senator Gore was not accurate. I was over there and spent a week. I visited the first plant that you mentioned, which is Calder Hall, of 140,000 kilowatts. Three of the four units were completed. The other was not completed and was not operating when I was there.

The second plant, Chapel Cross, I was told that it would not be worth my while to go there because it was just beginning to come out of the ground, and I would only look at a construction job with concrete being poured.

Next week, Sir Edwin Plowden will be over here, and I am sure he will give us accurate information on every one of these plants. I think the total of 3,300,000 kilowatts is correct, but I do not think that the schedules are correct.

Senator GORE. I will be glad to submit this for the record. The staff lists as sources Sir John Cockcroft, a statement by him on August 31, 1958, a personal communication on October 21, 1958, the Geneva paper that was read by Mr. Duckworth, and others, and then Nucleonics magazine, September 1958, and "The Nuclear Energy Industry of the UK." I submit what I have.

(The table referred to follows:)

United Kingdom power production reactors

Station	Output, electrical kilowatts	Status
Calder Hall	150,000	Completed.
Chapel Cross	150,000	Partially completed.
Berkeley	275,000	Under construction.
Bradwell	300,000	Do.
Hunterston	320,000	Do.
Hinkley Point	500,000	Do.
Trawsfynyd	400,000- 500,000	Scheduled.
Sizewell	650,000	Do.
Dungeness	400,000- 500,000	Do.
Total	3,145,000-3,345,000	

The following excerpt from "The Nuclear Energy Industry of the United Kingdom" by the United Kingdom Atomic Energy Authority (first published September 1958) outlines the British nuclear power program:

"The provisional proposals set out in the Government White Paper 'A Program of Nuclear Power' (Cmd. 9389, February 1955) were for 12 nuclear power stations, with a total output capacity of 1,500 to 2,000 megawatts. These stations were to be constructed and put into operation in the United Kingdom during the decade 1955–65.

"Toward the end of 1956 this program was reexamined. On March 5, 1957, the Minister of Power announced that, as a result of rapid technical advances, a substantial improvement could be made on the original program and a total output capacity of between 5,000 and 6,000 megawatts might now be achieved by the end of 1965.

"In October, the Chancellor of the Exchequer announced that as part of the reduction in public investment the rephasing of the nuclear power program might involve the postponement by 1 year of the date by which the capacity of 5,000 to 6,000 megawatts would be completed."

Mr. McCONE. All I can say is what I learned from a week's visit, sir.

Senator GORE. I was there and crawled through Calder Hall.

Mr. McCONE. You saw it then in its partially completed form.

Senator GORE. I believe I was there about 16 months ago and they expected to be in operation within a very few months on the second plant in Calder Hall.

Chairman ANDERSON. Lord Plowden will be here in a few days and we will ask the staff to contact such people as he may have with him and reconcile these figures in some fashion.

Senator GORE. I have finished, Mr. Chairman. Thank you.

Chairman ANDERSON. Mr. Bates.

Representative BATES. Mr. Chairman, I would like to return for a moment to the discussion which Senator Pastore started relative to our general philosophy in this field. We have heard a lot of people quoting kilowatts and number of reactors. To me that does not mean a thing. The important thing, as I see it, is the progress that we are making. Just to produce kilowatts or a large number of reactors does not necessarily mean you are making progress. Do you agree with that statement?

Mr. MCCONE. Yes, I agree with that.

Representative BATES. Are we producing or developing all kinds of real promising reactors in this country? Is that your philosophy?

Mr. MCCONE. We are not developing all kinds.

Representative BATES. But the real promising ones?

Mr. MCCONE. Our purpose is to develop the most promising kind and to keep our base broad enough so that if we encounter a disappointment in one type, we will still have others coming along. However, we are not going to develop all types because the combinations of types are just incalculable.

Representative BATES. You just better expressed what I had in mind, but the most promising ones you are developing.

Mr. MCCONE. That is right.

Representative BATES. You do not have a philosophy just to produce kilowatt hours or a large number of reactors just to say we have more than the Russians.

Mr. MCCONE. That is correct.

Representative BATES. To me that would be a very wasteful course to pursue.

Chairman ANDERSON. Senator Hickenlooper.

Senator HICKENLOOPER. Thank you, Mr. Chairman.

I think Mr. Bates covered the general subject that I wanted to bring out in my first question, that this is not a race just to produce more kilowatts than the Russians or we could have done that a long time ago. As I understand it, our policy is to search for the most promising and the most economical methods of producing power from atomic energy. Would you say that is our basic search?

Mr. MCCONE. That is right.

Senator HICKENLOOPER. Do you think, Mr. Chairman, that we have a more diversified program of research and development than any other country in the world, or do you have knowledge of that?

Mr. MCCONE. I know we have a more diversified program than any country to which I have access.

Senator HICKENLOOPER. Did you get any impressions last year or heretofore from any international conferences as to any comparison between our country and other countries as to the diversification and the extent of research and development?

Mr. McCone. The only three countries that are doing work on a large scale, of course, are the United States, the British, and Russia. I have commented on the British and the Russian programs. The French have done a good deal but not too much. The Germans are doing some very interesting work, particularly in the field of organic moderated plants. This probably relates to their penchant for chemistry and the fact that they have, through the years, been quite advanced in the field of chemistry. I think they feel and they hope that they can develop an organic moderator that might not experience some of the difficulties that the moderators we are using are witnessing, that limit the effectiveness of organic moderated plants.

Senator Hickenlooper. I want to ask you for the record so that we may have it cleared up, how do you use the term prototype or experimental prototype? Would you speak to that for a moment?

Mr. McCone. Yes. I look upon an experimental reactor or a reactor experiment as a plant which is primarily built for the purpose of testing out the developmental work that has been done in the laboratory by the scientists. The purpose of it is primarily for test and to demonstrate that the laboratory developments can be adapted on a reasonably large scale. It has no particular useful purpose as a power generator, although in some instances the adaptation of power is of some value. These plants, in my opinion, should for the most part be built by the Atomic Energy Commission on Atomic Energy Commission facilities, and if power is generated we should use it. This does not, however, foreclose the building of experimental reactors by private companies, and some have been built.

Senator Hickenlooper. In the main you consider a prototype reactor as one which ordinarily should be of sufficient size so that the results can be extrapolated into a useful commercial operation.

Mr. McCone. A prototype reactor is something quite different from an experimental reactor. A prototype reactor must be large enough so that the operation, the economies, the efficiency and the compatibility with an electrical system can all be demonstrated in a manner that can be extrapolated into large central power stations. That is the term we apply to the prototype.

Senator Hickenlooper. I have been interested in the past in the proposal which you brought out today, whether it is the first time it has been brought out publicly or not, for the contribution to capital cost construction, as I understand it, which might represent a substantial proportion of the difference in that capital cost between an atomic plant and a conventional plant. This seems to me to be a substantial departure from former positions. Is that correct, that it is a departure?

Mr. McCone. Yes, I think it is correct. I think it requires some changes in the law to do it.

Senator Hickenlooper. Do you have support for this position in the Administration or the Bureau of the Budget?

Mr. McCone. Yes, I have support for the idea of giving capital grants to the extent of 50 percent of the plant cost—that is the total plant cost—and this is exclusive of research and development and fuel assistance that is now provided. I have support on that in the Administration.

Senator HICKENLOOPER. Would these capital contributions be limited only to the reactor portion or the nuclear end of the project, or would it be extended to generators and things like that?

Mr. MCCONE. I would include the whole plant up to the buss bar, I would not limit it to the nuclear reactor.

Senator HICKENLOOPER. Would you also limit it to the difference in cost—that is, whichever might be lower—between conventional powerplants in a particular area, and the nuclear powerplant? In other words, if you contributed 50 percent of the cost, would it be possible that that 50 percent would bring the cost of that plant down below the cost of a conventional plant?

Mr. MCCONE. Yes, I would not do that. I would not go below. I would make the power user, public or private utility, put up at least the cost of the conventional plant. That certainly would be a fair and proper thing to do.

I think, incidentally, they should put up a little more than that, because all of them have facilities with the exception of the Rural Electrification groups, to spend some of their money, their reserves, and so forth, for developments which will be to their future benefit. I think they have to stretch that a little bit.

Senator HICKENLOOPER. I want to hurry on because I know there are others that have some questions, but there are a few I would like to ask you. Do you think that we should build another large pressurized-water plant?

Mr. MCCONE. As you know, we are making a study now. I think it is the agreed position that the developments that are going to come out of these families of plants that are now nearing completion, together with the very large expenditures on fuel development at Shippingport, would indicate it might be advisable to wait a little while before be build another large pressurized plant.

Senator HICKENLOOPER. That gets down to the matter of what you expect to accomplish in the future in efficiency with the very substantial expenditures, I understand, to be made at Shippingport of around $20 million. What do you expect to get as a result of that?

Mr. MCCONE. We expect to get higher density. We expect to get lower cost fuel elements. We expect to get improved burnup conditions. We expect to very materially improve the entire fuel cycle and the efficiency of the operation. I think that the prospect of this is sufficient to justify the proposed expenditures.

Senator HICKENLOOPER. With regard to the so-called delay on the Hallam plant, is that a delay that is dictated by the Commission, or is it a delay dictated by the mutual consent and appreciation of the problems of both the Commission and the public power corporation, or whatever it is?

Mr. MCCONE. I think it was suggested by the Commission as a result of the recommendations of our ad hoc committee, who went into this matter quite carefully. They pointed out to us that while the reactor experiment at Santa Susana was operating reasonably successfully, and was used as the basis for the design of the Hallam plant, there was in the background, untested and unproven, but still in their developmental stages, a very substantial number of technological improvements. If we could wait and test those all out in another reactor experiment, we would have a very much cheaper and a very much more

efficient plant at Hallam than we would if we build it now. There is no question about the fact that we can build it and get it going, but it would be quite expensive.

With that in mind, we asked the Hallam people to come down here. We have talked to them. They were very sympathetic to the idea, and they would be perfectly willing to work out a program with us, if we want to do it, so that it would fit into their power buildup and their requirements. They have been very cooperative. They would like to have a plant. They would like to have an efficient plant. They do not want to be left with a gap, and we are not going to break faith with them in that regard.

It is interesting that Mr. Starr, of International Atomics, in discussing this matter with us and with the Hallam people, made the point that if we had a problem of whether to build the experimental reactor or Hallam, he would feel that we should build the experimental reactor because of the importance of proving out these developments. If we build both of them together, then we get in the position that we are in with the Enrico Fermi plant, when we are building the EBR–2 and Enrico Fermi both at the same time. As a consequence, the Fermi plant cannot benefit by the improvements that we are going to prove out in the EBR–2. This is really, as I pointed out the other day in talking to the chairman, bad timing, it seems to me.

Senator HICKENLOOPER. Mr. Chairman, my own personal attitude has been one of a willingness to support to a substantial degree the building of prototypes by the Commission which will give answers to the questions of efficiency and cost and so on. But to me it is the height of fiscal irresponsibility to build great big industrial plants when we know in advance that every kilowatt that comes out of that plant is economically unsound from the standpoint of cost. It is a whole lot like the fellow who said he lost money on every banana he sold, but he made money on the volume. To build a big plant where you are going broke every day you operate it as a commercial enterprise, it seems to me the height of fiscal irresponsibility.

I think we can learn the lessons in substantial prototypes. I think that money is well spent. But when you start building commercial types that you know are going to be obsolete by the time they are completed, it should give us some pause for a little sober financial thought, especially when we do not have any particular shortage in this country of fossil fuel, and where we can produce these kilowatts today at a lower cost.

I have just one more comment, Mr. Chairman. I am very much impressed with your presentation of this program. I think it is a forward-looking, vigorous program. I congratulate the Commission on this presentation and on your vision and what you propose to do in a realistic, sound, orderly manner in developing this reactor program. I realize that there may be some differences of opinion and some differences of interpretation, but I want to say that I think you are going at this, you and the Commission, in a realistic way, and I think you will accomplish very substantial results for American continued leadership in this field, and for finding out the answers to cheaper and more economic power through atomic energy.

That is all, Mr. Chairman.

Chairman ANDERSON. Mr. Holifield.

Representative HOLIFIELD. Mr. Chairman, I have been trying to digest these many figures in the many different charts and schedules of items which have been authorized in the past and agreed upon by the committee and the Commission, and certain commitments which have been made by the Commission, in trying to the best of my ability to understand what the situation is. We did not have these latter statements of Mr. McCone until they were placed on the table today. Some of them, I think, came out late yesterday. As near as I can see, the AEC is requesting a total of about $115 million for all types of projects. That includes weapons, production, and research. This compares to an average of about $300 million a year that has been asked for and authorized for the last 4 years. So it is just about a third, as I see it, of what we have had in the past.

I am particularly concerned about the amount that has been proposed for the civilian atomic power program. As near as I can tell again from the figures, the net amount for 1960 is about $14,500,000 compared to $74,550,000 last year. I agree with Senator Gore on those figures. I note that there are a number of modifications and changes and these changes run counter to the legislation which has been passed, which was the direction of the Congress to the Commission. They include changes in some of the projects which, in my opinion, are questionable. I don't accuse the Commission of bad faith, but I do call to your attention that last August when the Commission was before the Joint Committee we inquired into the implementation of the program, and I questioned Mr. McCone on the gas-cooled reactor, the $51 million item which is now being sharply changed. In fact, it is being deleted, I believe, and a $30 million item put back in its place. It was reduced from $51 million to $30 million, $21 million being the reduction in the power features of it.

We questioned Mr. McCone on that, and Mr. McCone testified that under the invitation those proposals would have been in 30 to 60 days—speaking of the proposal for the gas-cooled reactor—and we would have to have those proposals in our hands some time late in November.

At that time we will know whether we can have what appears to be an acceptable proposition or whether we should proceed immediately with the design of our own reactor under title 2.

Mr. McCone said:

I am going to ask for apportionment of $6 million at this time so we can be prepared immediately upon the conclusion of these negotiations to proceed with title 2 if we do not get acceptable proposals. If we do get an acceptable proposal, we will report it to the committee and presumably will not proceed with title 2 design of our plant.

I further questioned on the matter on pages 37 and 38. I said that one of the facts that I recall was that this was to be constructed in such a way—speaking of this reactor—that natural uranium could be tested as well as slightly enriched, and we trust the Commission will keep in mind the criterion would not be changed in such a way that it will circumvent the purpose of the committee.

Mr. Foster at that time answered—I believe he was here on that occasion representing the Commission as General Manager or Acting General Manager—and he said that they had it in mind.

On the last day, on November 21, the Philadelphia Electric group and the General Dynamics submitted a proposal ostensibly to fulfill the invitation which had been extended to them. A little over a month later, in January, the General Counsel of the AEC held that it did not fulfill the requirements, but, instead of going ahead on phase 2, the detailed title 2 design, in further development of this type with the idea of the Government building it, it is my understanding—and I would be corrected if I am wrong—that there was a delay or a slowdown in title 1 design work, and title 2 design work has not been carried out, notwithstanding some 3 months has transpired since that time.

Now I understand that, notwithstanding the commitments we thought we had from the Commission and the clear direction under the law, there is going to be a complete modification of the so-called Kaiser study and you are not going ahead with it in the way it was intended.

Also, in testimony before us in May and June 1958, in the authorization hearings, pages 273 and 279, the Commission advanced several items. One was that they wanted to build a heavy water moderated power reactor of about 100,000 electrical kilowatts. I notice this is not included this year in your schedule.

Then, of course, there was the Pennsylvania Power & Light reactor where we went along with a $7 million appropriation and that has been canceled. As I understand, that was done at the wishes of the Pennsylvania Power & Light and the Westinghouse people on a technical ground. I certainly think that is justified, if they feel that the money would be wasted.

I note also that you proposed at that time that you would propose a small-scale pressurized reactor of 20,000 to 40,000 kilowatts, and that is not included.

Then the next item was the heavy water moderated gas cooled prototype reactor, the so-called Florida project of about 50,000 kilowatts. I see you have included that. This is an item that has already been authorized, but I understand that no contract has been signed on that.

You also had a heavy water moderated for the Carolina-Virginia group, which is authorized, and I understand the contract is signed on that.

Then the Chugach experimental plant of 17,000 electrical kilowatts, I understand for all practical purposes is canceled, although there may not have been a formal cancellation. This is also news to us, and I have not had any time to study the reasons.

As I understood there was a study group that was studying the feasibility of that that was to make a report on that. Has that group made the report, Mr. Chairman?

Mr. McCone. Not yet; no.

Representative Holifield. Are you awaiting final action on that, or have you already notified the people that Chugach would be canceled before you get your study group report?

Mr. McCone. I would like to answer Mr. Holifield's question. It would take me a long time to do it. I would like to make one statement. I just don't know why I am here, Mr. Chairman. I really don't know why you asked me up here because I have spent 2 days

now trying to give you the background, the reasoning why we are doing these things, which we arrived at after months of work. I find that Mr. Holifield makes a press release criticizing everything. He had it all printed and written up before he even heard what I had to say. So I wonder why I came up here.

Mr. HOLIFIELD. I had nothing written up.

Mr. MCCONE. What is this?

Mr. HOLIFIELD. This is a press release.

Mr. MCCONE. The press release is "that I am disappointed in the inadequacies," I am concerned about the cancellation of Chugach, postponement of Consumers Public, modification of Kaiser, elimination of liquid metal. I have explained them all this afternoon. I wonder why you do things like that. I am working hard at this job, Mr. Holifield, day and night, and I don't like to have this thing released.

Mr. HOLIFIELD. What do you mean, you don't want it released.

Mr. MCCONE. If you want me to come up to testify, listen to me and then make up your mind what you think about what I say.

Mr. HOLIFIELD. I did listen to you and this came off the press not over 30 minutes ago. This came off the mimeograph machine and it is my comment which I am making orally right now and I am putting it out in printed form and it has been prepared not more than 30 minutes. I OK'd the release of this just about 30 minutes ago. I am sorry that you take exception to the fact that I am disappointed in the program that you have put up here because your program is completely different from what the committee has asked for in its legislation in the past and has authorized and directed under the law. You are accepting exotic proposals such as the General Dynamics proposal and you are turning down the Chugach thing on the ground it is exotic but you are coming before us for authorization for another, jumping completely over every experimental model and every prototype. As far as the cancellation of the Chugach thing is concerned, this was a Commission proposal. It was not a committee proposal. So was the Hallam, Nebr., proposal. That was proposed to us by the Commission. The committee did not originate these programs that you are now turning your back on. We went along with you on them because they were proposed by the previous Chairman and the previous Commission members. If you want to turn back on the programs which your own Commission has advanced in the past that is your business, but certainly when the committe has directed by law and the Congress has directed by law certain proposals, to have you modify them and change them so sharply as you have is certainly something of concern.

Mr. MCCONE. All I have heard all afternoon is how bad the program is. Senator Gore has made it abundantly clear. I have made some recommendations to change it and to improve it. In the particular gas field, I have shown you a way that we can proceed, courageous as it is. It would put us years ahead of the position that Senator Gore fears and that is the advancement of the British. This is a challenge which I would recommend that we take. I think that the program that was outlined last year which was made in the light of the technology at hand warrants modification, sir, and this is why I am recommending that it be modified.

As regards the Chugach, this may prove to be a type of plant that we should develop, but certainly my reasons for recommending the cancellation are because of the remote location. I think that is valid reasoning.

Representative HOLIFIELD. Mr. Chairman, I am not going to quarrel with you in your judgment nor am I going to become heated about it. All I have to say is this: It is an old, old axiom, "If you can't stand the heat don't go into the kitchen." We get a little heat up here, too. So I hope that there is nothing personal I have said that has offended you from a personal standpoint.

Mr. MCCONE. Nothing personal at all.

Mr. HOLIFIELD. I hope we can agree to disagree on some of these principles without any personal heat because I personally have no desire to have a personal quarrel with any member of the Commission and certainly not with you.

(The press release discussed above follows:)

[No. 203, for immediate release Wednesday, Feb. 18, 1959]

From the Office of the Joint Committee on Atomic Energy:

Congressman Chet Holifield (D., Calif.), chairman of the Subcommittee on Legislation of the Joint Committee on Atomic Energy, announced today the receipt by the Joint Committee of the proposed AEC authorization legislation for fiscal year 1960.

In commenting on the legislative proposal, Congressman Holifield stated as follows:

"I am disappointed at the inadequate support the executive branch proposes to give to its atomic energy program through new capital facilities and improvements and the cooperative power program. AEC is requesting a total of only $115 million for all projects, including weapons, production and research, compared to the average of $300 million authorized for the last 4 years since the program leveled off.

"I am particularly distressed at the pitifully small program proposed for the civilian atomic power program. AEC has requested only a net amount of $14 million for its Government civilian power program facilities, and no additional funds for its so-called cooperative program of assistance to private industry in the development and construction of atomic powerplants.

"I am also concerned with the cutbacks in the civilian atomic power program revealed in the authorization bill and the current 202 hearings. These cuts included the following:

"1. The cancellation of the Chugach cooperative project;

"2. The postponement of consumers public Hallam project, Consumers Power District of Nebraska;

"3. The modification of Kaiser-ACF project;

"4. Elimination of Liquid Metal Fuel Reactor Experiment.

It is possible that other cuts may be hidden in the fine print.

"In view of the cutbacks in the current program and the inadequate support for the future, it is difficult for me to believe that the AEC is genuinely assuming a role of 'positive and vigorous leadership' in the civilian program as their Chairman is now claiming. The only initiative AEC is showing is in cutting back projects, and in providing greater assistance to certain groups."

In conclusion, Congressman Holifield had the following to say about the authorization proposal:

"I regret to say that the 1960 proposal was submitted with no prior consultation and contains procedural features which are entirely unacceptable. Thus, for example, the specific projects are not numbered, because if they were the

Commission would have to stick with the purposes of the project as set out in the justification data. In the past 2 years we have been quite concerned over AEC's attempts to wriggle out of legal and moral commitments made to the Congress and the public. This proposal could give them carte blanche to do anything they choose with the money Congress authorizes and appropriates."

ATTACHMENT No. 1

FEBRUARY 18, 1959.

CIVILIAN POWER PROGRAM—COMPARISON OF FUNDS AUTHORIZED BY FISCAL YEAR 1959 AUTHORIZATION ACT (PUBLIC LAW 85-590) WITH FUNDS REQUESTED BY AEC PROPOSED AUTHORIZATION BILL FOR FISCAL YEAR 1960

Public Law 85-590 (fiscal year 1959)

AEC PROGRAM

59-d-7	Modifications to OMRE, EBWR, Borax	$6,300,000
59-d-8	Heavy water component, test reactor	8,000,000
59-d-10	Gas-cooled power reactor	[1] 51,000,000
59-d-12	Design study, heavy water	2,500,000
59-d-13	Design studies, 3 reactors	6,000,000
59-d-14	Design study, nuclear superheat	750,000
	Total	[1] 74,550,000

COOPERATIVE PROGRAM

Sec. 109	Increase in cooperative program	[1] 25,198,000

[1] 59-d-10 alternatively available for AEC construction or cooperative program under sec. 110 of Public Law 85-590.

AEC proposed bill for fiscal year 1960

AEC PROGRAM

Sec. 101(e)	Modifications to EBR-1	$1,000,000
Sec. 101(e)	Portable gas-cooled	2,500,000
Sec. 101(e)	Modifications to MTR-ETR	2,000,000
Sec. 107(a)	Flexible experimental gas-cooled	30,000,000
Sec. 110	Four experimental and prototype	[1] 30,000,000
	Total	65,500,000
Minus sec. 107(a)	Stricking 59-d-10 gas-cooled prototype	51,000,000
	Total	[1] 14,500,000

COOPERATIVE PROGRAM

Sec. 111	R. & D. assistance	5,000,000
Sec. 112	Advanced high-temperature, gas-cooled	14,500,000
	Total	[1] 19,500,000
Minus Sec. 113	Decrease in cooperative program	—20,000,000
	Total, minus	500,000

[1] $30,000,000 for experimental and prototype power reactors is for construction "either in cooperation with industry or by direct Government contract" under sec. 110 of proposed bill.

ATTACHMENT No. 2

FEBRUARY 18, 1959.

AEC CIVILIAN REACTOR DESIGN AND CONSTRUCTION PROGRAMS COMPARISON OF AEC OFFICIAL STATEMENTS IN 1958 AND 1959

PROTOTYPE AND EXPERIMENTAL REACTORS PROPOSED FOR FISCAL YEAR 1960 IN HEARINGS ON ATOMIC POWER PROGRAM IN MAY–JUNE 1958 (AEC AUTHORIZATION HEARINGS, 85TH CONG., 2D SESS., PP. 273–279)	PROPOSED REACTOR PROTOTYPES AND EXPERIMENTS AS SET OUT IN CHAIRMAN MCCONE'S FEB. 17, 1959, STATEMENT FOR FEBRUARY 1959 "202" HEARINGS AND FISCAL 1960 AUTHORIZATION PROPOSAL
I. PROTOTYPES	I. PROTOTYPES
1. Heavy water moderated power reactor (100,000 KWE[1])	1. Not included.
2. Single region aqueous homogeneous reactor of large scale—Pennsylvania Power & Light (100,000 KWE)	2. Canceled.
3. Small-scale pressured water (20-000-40,000 KWE)	3. Not included.
4. Heavy water moderated gas-cooled prototype reactor (east coast Florida) (50,000 KWE)	4. Included—has been authorized. No contract signed as yet.
5. Heavy water moderated and cooled prototype reactor (Carolinas-Virginia) (17,000 KWE)	5. Included—authorized and contract signed.
6. Heavy water moderated, sodium-cooled experimental plant (Chugach) (17,000 KWE)	6. Canceled.
7. Process heat prototype reactor_____	7. Included.
8. Gas-cooled prototype (40,000 KWE)	8. Canceled gas-cooled prototype power reactor.
	9. Advanced boiling water prototype.
	10. Advanced high temperature, gas-cooled reactor (PE–GD).
	11. Small nuclear powerplant, (20,000 KWE).
	12. Delayed Hallam sodium-cooled reactor—Consumers Public Power of Nebraska (75,000 KWE).
II. REACTOR EXPERIMENTS	II. REACTOR EXPERIMENTS
1. Organic moderated reactor experiment.	1. Included.
2. Intermediate-sized two-region aqueous homogeneous reactor experiment (design).	2. Not included.
3. Molten salt experimental reactor___	3. Not included.
	4. Borax V (40,000 WKH[2]).
	5. Experimental sodium-cooled reactor (design).
	6. Flexible experimental gas-cooled reactor.
	7. Canceled liquid metal fueled reactor experiment.

[1] KWE—kilowatts of electrical power.
[2] KWH—kilowatts of heat power.

Senator GORE. Mr. Chairman, would the Congressman yield?

Mr. HOLIFIELD. In view of the lateness of the hour and Mr. Weaver's request, I will desist from further questioning.

(For further details on this discussion, see the hearings on AEC authorizing legislation, fiscal year 1960, morning and afternoon sessions of February 27, 1959.)

Senator GORE. I only want to say in view of the comment of the distinguished Chairman that he should not be surprised that the program presented by the Commission undergoes searching examination.

Mr. MCCONE. That is why it is presented.

Senator GORE. Congress has its responsibility.

Mr. MCCONE. That is why it is presented. That is why I presented it in such detail.

Senator GORE. That is why I attempted to analyze it most carefully.

Mr. MCCONE. We will appreciate your advice and direction. You have been in this for a long time.

Senator GORE. I find the program as presented timid and wholly inadequate from my point of view and in the exercise of my responsibility. In challenging its adequacies and in making an analysis of it, I have undertaken to do so without malice, without heat and in the most pleasant way possible. Upon several occasions I have expressed my appreciation for the warm personal equation which I have enjoyed with the distinguished Chairman.

Mr. MCCONE. Senator, there is not one expression, there was not one view of yours that I haven't the greatest respect for. I am going to take everything that you have said into very serious consideration.

Senator GORE. Thank you, Mr. Chairman.

Mr. MCCONE. Very serious consideration.

Representative VAN ZANDT. Mr. Chairman, may I make an observation at this time?

Mr. Chairman, I want to join the Senator from Iowa in his commendation of your efforts as well as the far-reaching program you have presented to the committee. I know you started on the program last October and enlisted the aid of many experts who assisted in putting the program together. Therefore this program stems from a lot of work on the part of yourself and associates. I want you to know also that I disagree with these news releases that are being distributed almost before the witness has had an opportunity to complete his statement. It has not only happened today but on previous occasions.

Chairman ANDERSON. Mr. Chairman, we will try to find a date that is mutually agreeable and have you back at a later time.

Mr. MCCONE. Thank you very much.

Mr. LIBBY. It is not tomorrow?

Chairman ANDERSON. It cannot possibly be tomorrow. We have witnesses scheduled.

(A letter dated March 13, 1959, providing supplementary information on the AEC civilian atomic power program, follows:)

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., March 13, 1959.

Hon. CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy,
Congress of the United States.

DEAR SENATOR ANDERSON: During the course of the opening session of the 202 hearings, Chairman McCone offered to provide various items of supplementary information for the record concerning the Commission's civilian atomic power program. These data are presented below.

1. Cost of first SNAP–III Thermoelectric Device

Research, development, and manufacture of device—Minnesota Mining & Manufacturing Corp	$15,000
Research, development, assembly, and testing, Martin Co	8,000
Encapsulation of isotope, Mound Laboratory	3,300
Subtotal	26,300
Cost of Polonium 210	15,000
Total cost	41,300
Estimated cost of additional devices:	
Device manufacture	7,500
Assembly and testing	2,500
Encapsulation	3,000
Subtotal	13,000
Isotope	(1)

[1] Cost will vary with isotope selected and quantity of isotope used.

2. Firms retired from atomic energy business

Four companies who actually entered the atomic energy business and produced a product for sale have since announced their retirement from the field. They are: Daystrom, Koppers, Bell Aircraft, and Raytheon. In addition, several companies employed small staffs to explore the prospects of entrance into the field and subsequently decided against it. Examples of this type are: Dow Chemical, Chrysler Corp., Thompson Products, and Foster Wheeler.

The above information has been corroborated by the Atomic Industrial Forum, Inc.

3. Cheapest reaction construction cost in the United States and abroad in terms of kilowatt hours

The cheapest construction cost for a reactor in which the Government is participating is the cooperative agreement we have entered into with the Northern States Power Co. Capital costs of $350 per kilowatt-hour are estimated under this agreement. An annual fixed charge of 14 percent and a load factor of 80 percent result in a cost of 7 mills per electrical kilowatt-hour.

As Mr. McCone indicated in his testimony, the proposed SENN plant in Italy is the cheapest plant to be constructed abroad at the present time, to our knowledge. Capital costs of $325 per kilowatt are estimated for this plant and application of the same fixed charges and load factor results in a cost of 6.5 mills per kilowatt-hour.

The cost of the first core is excluded from the above computations.

4. Number of employees engaged in civilian power development program in Division of Reactor Development

The scientific and technical staff level of the Office of the Assistant Director for Civilian Reactors is 28. However, it should be recognized that several other Offices of the Division of Reactor Development devote all or part of their effort to the civilian power program. For example, the staff of the Office of the Assistant Director for Nuclear Technology participates actively in and provides substantial assistance to the civilian reactor program in the fields of fuel fabrication, reactor physics, environmental and sanitary engineering, reactor component development, and separations and processing. The program of the Office of the Assistant Director for Maritime Reactors is devoted exclusively to civilian applications of

nuclear power to the propulsion of ships. In addition, one segment of the program of the Assistant Director for Naval Reactors is devoted to the advancement of the pressurized water reactor concept and the work accomplished under the program augments and complements the civilian power program.

A summary of the Division of Reactor Development scientific and technical personnel who direct all or most of their effort to the development of reactors for civilian application is presented below in tabular form.

Director's Office	3
Civilian reactors	28
Nuclear technology	19
Naval reactors (on PWR)	7
Maritime	10
Total	67

The above figures do not reflect the positions of the Director and Deputy Director who devote a substantial portion of their time to the civilian power program, nor do they reflect the secretarial and clerical personnel assigned to the various offices.

Sincerely yours,

A. R. LUEDECKE, *General Manager.*

Chairman ANDERSON. Mr. Weaver, we are very happy to have you here. We are happy to have Westinghouse officially represented. It has had a great part in the development of our atomic program. We appreciate your being here today.

STATEMENT OF CHARLES H. WEAVER, VICE PRESIDENT, WESTINGHOUSE ELECTRIC CORP.

Mr. WEAVER. Thank you very much, Mr. Chairman.

I really feel quite humble stepping in here right after Mr. McCone and his presentation. I didn't have the advantage of listening to the entire discussion.

During the past year, and even since I was last before the committee in the spring in connection with the Euratom proposals, there has been much constructive thinking on atomic power development.

On behalf of Westinghouse, I would like to commend the Joint Committee and the Atomic Energy Commission for sponsoring the studies which preceded publication of the committee's proposed program and the report of the ad hoc committee of the Commission. The reports show a deep comprehension of basic technical and developmental problems.

In October of 1957, in a keynote speech before the Atomic Industrial Forum, I called for restatement of national policy on atomic power. While the committee and Commission reports are not official, it seems safe to say that today we are on the threshold of this new policy.

The findings in the Joint Committee's report and of the ad hoc committee are essentially harmonious. In important places like their "objectives" they are in substantial accord.

Today I would like to comment on some specific things in the two studies and suggest areas where ideas might be expanded or modified.

I suppose over the years I have become identified with one statement—that the big problems in atomic power development are technical problems—that only extensive research and development can bring about economic nuclear power. After reading the committee

and the Commission reports, I felt as if I had been invited into select company, for the same theme repeats itself.

To meet the objectives of the proposed program and the ad hoc report—of fortifying the position of the United States in the technology of nuclear power for civilian use and achieving economic nuclear power on a given timetable—it is obvious that normal economic incentives are inadequate to support fully the level of research and development which will be necessary to solve the technical problems. Help will be needed, particularly in the areas of fuel development and the development and construction of reactor prototypes. I consider a prototype to be a plant ranging from, say, 10 to 100,000 kilowatts, with the size dependent upon the particular reactor type and its state of development and the kind of questions to be answered by the plant. The number of prototype plants required in order to prove the feasibility of a large-scale plant will also be different for different reactor types.

The toughest of the technical problems are those which just can't be solved by theoretical means alone. In the case of the pressurized water reactor, and thanks to the naval reactors program, there have been successive generations of prototype plants. Only now, after much operating experience and operational testing, is sufficient information available nationwide to talk about a really large-scale plant. We have proposed to build a 330,000-kilowatt pressurized water plant, which we believe could produce competitive electric power in some higher fuel cost areas of the United States, but this too would require research and development work, particularly in the design of the reactor core and its fuel.

Even with the national experience in water reactors and all the naval work, water reactors other than the simplest pressurized variety still need more prototype experience before sound decisions can be made to go ahead with large-scale plants.

An example of this is the pressure tube prototype reactor which we are now developing with the Carolinas-Virginia Nuclear Power Associates, and with Government assistance. One day this type could offer a very key advantage for very big plants. We view the pressure tube concept combined with boiling and integral superheating as the most advanced of the water systems. But prototype experience comes first.

The ad hoc committee report refers to both reactor experiments and prototypes and I would like to distinguish between them. I visualize a prototype reactor as one for which a relatively long life is planned, and from which such information as lifetime in the fuel cycle can be obtained as well as confirmation of plant design features.

In contrast, reactor experiments could be one-shot construction jobs testing the feasibility of a single idea, with an ultimate view toward cessation of reactor operation if the idea doesn't pan out. It is the true protoype which offers so much information and assistance for the future.

But prototypes must be designed toward specific objectives or else the information developed cannot be measured adequately. In addition they must be operated by a competent organization if there is to be a good job of analysis and a full comprehension of the phenomena. I cannot overemphasize the importance of this point.

The Joint Committee an ad hoc committee reports both touch upon the possibility of building large-scale plants in the case of some reactor types and the further possibility that such large-scale plants might be constructed by the Government in the absence of industry proposals. Here I would emphasize the word of caution stated by the ad hoc committee in their report. The absence of industry proposals could mean that there is insufficient prototype experience on that reactor type and that a sound decision cannot be made to proceed with a large-scale plant. In this event, the Government's invitation should probably be recast to specify a smaller prototype.

The question of Government financial contributions for capital expenditures in reactor construction raises the same point. Undoubtedly capital assistance would greatly accelerate the construction of prototype reactors. However, I would be cautious in granting capital support for large-scale plants. It would seem that if capital support were needed for a large plant, perhaps inadequate prototype work had been done.

In terms of the technical problems and the information we need, much more information is needed on the fuel cycle.

We recently announced that we will develop and construct a small water reactor to hook on to a steamplant of the General Public Utilities Corp. A primary function of this plant will be to obtain reactor design and fuel-cycle information for commercial water reactors. Obviously, very much more work is needed. The design of reactor cores and developments related to the fuel cycle have been, and remain, the key to the whole problem of making heterogeneous reactors economic.

It seems that it is far too early for our country to standardize on any particular reactor type. Each of the industrial participants in the atomic energy program, such as we at Westinghouse, now have the guidance of specific objectives and philosophy from the committee and the Commission. We will cooperate and support to the greatest extent possible a broad program of research and development aimed at getting the answers. For example, in getting the badly needed information on the fuel cycle. Development work is needed for every really promising type of reactor—programed or proposed for the future. Different types will, of course, have different development time scales.

We have been supporting such broad research and development rather than using all of our resources to advance any one type of reactor for immediate commercial exploration.

Before concluding, I would like to depart from my formal statement for just a moment. Since preparing the remarks which I have just read, I have had the opportunity to read the testimony presented to your committee yesterday by Chairman McCone of the Atomic Energy Commission. I am pleased that testimony included a description of the Commission's proposed civilian nuclear power program. Although I shall look forward to studying the Commission's statement more thoroughly on first reading it appears to me to be most realistic and compatible with the two reports that I have referenced. I am delighted with the Commission's assurance of positive and vigorous leadership.

In closing, I would like to thank the committee, and again commend the Commission for pointing the way to a new atomic power policy. During what I have recently called the decade of decision ahead, it could be a healthy thing for the Government and our industry to debate or disagree on the merits of proposals—project by project. The important thing is that we all agree on a development philosophy. It seems to me that we are in a position to do this now.

Thank you, Mr. Chairman.

Chairman ANDERSON. Senator Hickenlooper.

Senator HICKENLOOPER. I have no questions.

Chairman ANDERSON. Mr. Van Zandt.

Representative VAN ZANDT. Mr. Weaver, during the afternoon someone has mentioned—probably Chairman McCone—that for the fiscal year of 1960, $22 million would be allocated to the Shippingport project. Does this mean that $22 million is necessary to operate the Shippingport reactor?

Mr. WEAVER. Mr. Van Zandt, I do not have the figures at my fingertips and I would hesitate to answer that question.

Chairman ANDERSON. We can supply them to you if you want them.

Mr. WEAVER. I don't think I should comment on them at this point, Mr. Chairman. I can't believe it is costing that much to operate the reactor.

Chairman ANDERSON. There are two $9-million items and a $2-million item. I have not seen it recently but I am sure that is what it was.

Mr. WEAVER. I have not seen the figures.

Mr. RAMEY. $2 million for operation, one of the $9-million figures is the preparation of advanced type of fuel.

Mr. WEAVER. This was my understanding.

Representative VAN ZANDT. Is it not true, Mr. Weaver, that we are spending $18 million on research and development as far as the Shippingport reactor is concerned and only $2 million is necessary for the operation of the reactor for the next fiscal year?

Mr. WEAVER. I understand that these figures are correct.

Chairman ANDERSON. Senator Gore.

Senator GORE. No questions.

Chairman ANDERSON. Mr. Hosmer.

Representative HOSMER. No questions.

Chairman ANDERSON. Mr. Bates.

Representative BATES. I have no questions.

Chairman ANDERSON. I want to ask you a question or two about the word "prototype." We get new terms. I talked about dirty bombs at one time and I found that nobody heard of a dirty bomb before. There were salted bombs and unsalted bombs.

Experimental prototype, prototype, and so forth, keep coming into it. Can you differentiate? You said you thought that Mr. McCone's presentation agreed with the two reports turned in by the ad hoc committee and the Joint Committee.

Mr. WEAVER. I thought so.

Chairman ANDERSON. This is as far away as it can be on this question of prototypes.

Mr. WEAVER. I didn't sense that. The thing I tried to do is to distinguish, and I did hear Mr. McCone also comment on this ques-

tion earlier, on the difference between a prototype and a reactor experiment. I think a prototype can be a plant of greatly varying size, depending upon the reactor type and upon what you are trying to prove from that particular prototype.

Chairman ANDERSON. We have been talking about first generations and second generations and building those by the Government until you get up to the point where they are commercially attractive or partially so, and then private industry might do it. That was somewhat the philosophy in the Joint Committee's report and the ad hoc committee's report. If you say that the Government shall not build anything, as I understand the presentation from the Commission to be, then you are a long ways from that.

Mr. WEAVER. I did not understand that. I thought it was compatible with my thinking, which would be that we don't take chances on large plants with severe technical problems facing us and economics against us when those points can be proven and we can gain the necessary knowledge to take that step through smaller prototype plants. These prototypes could be one for a specific type or it could be a series of them as necessary to arrive at that point when it would be reasonable to venture a large-scale plant.

Mr. RAMEY. I think the staff report made it clear that you would not jump to a large-scale prototype reactor without going through the intermediate steps.

Mr. WEAVER. I felt that, Mr. Ramey.

Mr. RAMEY. On the other hand, the staff report did state that on so-called experimental first generation prototypes you would not put those up for grabs. The Government should go ahead and build those and not get into the hassle that has happened in the case of the gas-cooled, homogeneous, and heavy water natural uranium type reactors.

Chairman ANDERSON. If you can give us any help on what you understand by reactor prototypes, what the Commission understands by experimental prototypes and what we thought we understood by prototypes we would be glad to have it at any time.

Mr. WEAVER. I shall be very glad to discuss that further.

Representative HOSMER. I am just wondering, Mr. Weaver, throughout your experience in this field do you visualize that someday we will settle down on one particular type of reactor that is the reactor, or will it be more or less like the automobile, we will end up with quite a variety.

Mr. WEAVER. I think it is too early to say. I don't believe that for a long while you can identify one single reactor type that is going to be good for all applications, all size plants, all locations of plants, and so forth. Where we will be 20 or 30 years from now is another matter. We may be close to what is an ideal plant at least for large central station applications.

At the present time I certainly recommend that we have a reasonably broad program of research and development covering those promising reactor types.

Representative HOSMER. Do you visualize that you will have to get your steam temperatures up to those of modern conventional plants eventually?

Mr. WEAVER. I believe that steam conditions approaching what we consider normal today are quite necessary in achieving the ultimate design of a central station plant. This does not mean that the conditions we can achieve today would not yield a plant which might in large sizes be economic in high fuel cost areas. But when we are reaching for the low power cost areas of our country we are certainly going to have to go just as far as we can in improving steam conditions as well as the other characteristics of the plant.

Chairman ANDERSON. Thank you very much. I am sorry you had to wait so long, sir.

Mr. WEAVER. Thank you, sir.

(Whereupon, at 5:10 pm., Wednesday, February 18, 1959, the committee was recessed, to reconvene at 10 a.m., Thursday, February 19, 1959.)

DEVELOPMENT, GROWTH, AND STATE OF THE ATOMIC ENERGY INDUSTRY

THURSDAY, FEBRUARY 19, 1959

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C.

The committee met, pursuant to recess, at 11 a.m., in room P–63, the Capitol, Senator Clinton P. Anderson, vice chairman of the Joint Committee, presiding.

Present: Senators Anderson, Pastore, and Aiken; Representatives Holifield, Van Zandt, and Hosmer.

Also present: James T. Ramey, executive director; John T. Conway, assistant staff director; David R. Toll, staff counsel; George F. Murphy, Jr., professional staff member; Edward J. Bauser, technical adviser, Joint Committee on Atomic Energy.

Chairman ANDERSON. The committee will be in order.

Our first witness this morning is Mr. Charles S. Rockwell, president of the Ford Instrument Co., a division of Sperry Rand Corp.

Mr. Rockwell, we are very glad to have you with us, and happy to have your statement at this time.

STATEMENT OF CHARLES S. ROCKWELL, PRESIDENT, FORD INSTRUMENT CO., DIVISION OF SPERRY RAND CORP.

Mr. ROCKWELL. Thank you, Mr. Chairman. I would like to thank you for this opportunity to testify before your committee. I am Charles S. Rockwell, president of Ford Instrument Co., a division of Sperry Rand Corp. I am speaking on behalf of a group of three companies to discuss, first, the need for an American nuclear merchant marine in being, and, second, a program which our group has developed for taking positive action to accomplish this objective in the shortest possible time.

I would like to emphasize that this is not a proposal but a recommended course of action aimed at meeting a most important objective.

The U.S. Government has for years been engaged in a multi-billion-dollar program aimed at replacing existing ships of the American merchant marine. The new ships being built are bigger, faster, and somewhat more efficient than their older sisters, but their operating and construction costs are high, and going higher. As a result, the present American merchant fleet continues to operate at a decided economic disadvantage against foreign vessels. We are convinced that the early application of nuclear power to certain classes of merchant vessels, particularly tankers and bulk carriers, can give American flag

operators a much needed boost in operating efficiency by reducing fuel costs and increasing cargo carrying capacity.

In the United States we have one great potential advantage over foreign merchant marines: The large and effective atomic energy program under the U.S. Atomic Energy Commission. We believe that if the American merchant marine is to again achieve a firm competitive position in world commerce it must take full advantage of this potential. No time can therefore be lost in the development of practical nuclear power for our merchant ships. We believe that industry must intensively develop, under the U.S. atomic energy program new applications for nuclear power which show strong economic promise.

As evidence of our convictions I am pleased to announce that the Isbrandtsen Co., Maryland Shipbuilding & Drydock Co., and Ford Instrument Co., a division of Sperry Rand Corp., have joined in a group project to install an advanced nuclear reactor—a gas-cooled, high-temperature steam reactor system—in an existing tanker in a minimum period of time. Together we present seasoned, experienced, and successful management in the fields of ship operation, design, and construction, and nuclear energy.

I know you are all familiar with the Isbrandtsen Co. This company, long established and successful operators of American flag vessels in round-the-world service, has pioneered many advanced methods of operation. Isbrandtsen's active interest in nuclear power for merchant ships, beginning with the President's announced plans for the peaceful use of nuclear power in 1955, has led them to intensive studies of various types of nuclear power systems. Their participation in this project is based on their independent decision that the gas-cooled reactor, generating superheated steam, offers the best economic promise for nuclear propulsion in the near future. Isbrandtsen will provide guidance for our program from the operating standpoint, and will prove the system in actual operation in their merchant fleet.

The second organization in our group is the Maryland Shipbuilding & Drydock Co., a concern with complete facilities and long experience in construction, conversion, and repair of merchant and naval vessels. This company also manufactures a wide variety of industrial and marine power equipment which will directly contribute to our program. Maryland Shipbuilding conceived and pioneered with great success the "jumboizing" technique, by which tankers are increased in cargo capacity. This technique is an important factor in the plan by which we will rapidly achieve actual operation of our proposed reactor system. Like the Isbrandtsen Co., Maryland has thoroughly investigated the problem of economic nuclear power for merchant ships and has reached the same conclusions. This company will do the naval architecture and construction required by our project.

Ford Instrument Co., a division of the Sperry Rand Corp., one of the largest industrial organizations in the United States, is the third member of the group. Ford Instrument Co. is well known for its many years of experience in the design of military equipment, and for its work in nuclear energy. Our company has been carrying out theoretical studies and experiments in the civilian high temperature gas-cooled reactor field for a longer time than any other industrial firm in the United States. Our work has been supported by both

the Atomic Energy Commission and our own company. We will do the reactor engineering and will design and build the reactor system in this project.

We would like to express our appreciation for the continuing cooperation and great assistance of Mr. Richard Godwin and the Maritime Reactors Branch of the Atomic Energy Commission, from the very beginning of this program.

In order to best utilize existing technology and gain practical operating experience with minimum delay, we intend to construct an advanced type of gas steam reactor system in a hull section duplicating that of an existing ship. After adequate test operation, this hull section, with its nuclear powerplant, will be installed in the ship for which it is designed by a process similar to the "jumboizing" technique used in the enlarging of existing tankers. By this method we avoid the necessity to construct a ship for the purpose of proving out the reactor, and the alternate necessity to take an existing ship out of service for a long period of time required for construction and prove-out of the reactor.

More important, however, is the fact that our plan eliminates the high cost and long delay inherent in the usual procedure of construction of a land-based reactor, engineering proof of the design, followed by construction of a nearly identical unit for operational use. One reactor will serve us as both prototype and operating unit. This concept has many important advantages which I will describe shortly, but most important of all, it is the fastest possible way to get a proven reactor of advanced design seaborne and operating in the merchant fleet.

It is our plan to build a gas-cooled reactor capable of generating superheated steam of quality consistent with the most modern marine powerplant practice. The reactor and its auxiliaries will be installed in a modern steam-turbine-powered vessel of the SS *Hans Isbrandtsen* class, a modern supertanker launched by Isbrandtsen last July. The existing main propulsion machinery will be retained essentially intact. The reactor, its auxiliaries and containment vessel will be erected in a newly constructed hull section duplicating a section of the *Hans Isbrandtsen*, and floated to a secluded area for test operation. After the reactor has been successfully demonstrated, the hull section will be returned to the yards of the Maryland Shipbuilding & Drydock Co., and installed in the vessel, replacing a similar section which will have been previously removed.

By means of this conversion technique, we will have our vessel ready when the reactor is ready, with minimum out of service time for the ship. We achieve substantial savings in time by utilizing an existing hull and its existing propulsion machinery, and by eliminating the need for a prototype reactor. This plan will best achieve our objective of producing an operating vessel with an advanced nuclear powerplant at an early date.

An added advantage of this jumboizing plan is the fact that the ship's boilers remain intact providing a standby system capable of full seapower. Only a small fuel oil reserve is required for this purpose.

The selection of a gas-steam reactor system for this project was made on the basis of a number of technical and economic considera-

tions. The reactor itself is helium cooled, graphite moderated, and fueled with stainless steel clad uranium dioxide pellets, having a gas exit temperature of 950° F. Superheated steam is generated at 640 pounds per square inch and 850° F., consistent with modern marine practice. Because of the relatively low design pressures and temperatures (both steam and gas), and the choice of an inert coolant, there is no requirement for exotic materials or sophisticated metallurgical techniques in the reactor. The planned reactor represents a considerable advance, and will be capable of further increase in capability. Even with present fuel technology, temperatures several hundred degrees higher than those planned are possible, and as marine steamplant technology progresses, this reactor will move ahead with it. Additionally, as fuel technology improves itself, even higher level performance can be predicted.

Ford Instrument Co. has conducted "in pile" tests on samples of the proposed fuel pellets at the Brookhaven National Laboratory with excellent results. The tests were made at temperatures far exceeding our planned design operating temperature.

The control rod drive mechanism which will be used has been designed and built by Ford Instrument Co. It has been successfully cycled, at higher than operating temperature, many times more than can reasonably be expected in the reactor's lifetime.

There are unique advantages to the gas-steam system for marine propulsion. It is not affected by pitch and roll; no radioactive steam can reach the turbine, and, perhaps most important, there will be no necessity for the discharge of radioactive wastes. In addition, the reactor system has a slow thermal response, a negative temperature coefficient and a low level of stored coolant energy. These factors, combined with the extremely reliable control mechanism, insure safe operation at all times. The system has a simple primary loop and uses a low enrichment nuclear fuel, which will contribute to overall economy.

The technology which we are using as a basis for this design follows the central path of reactor development in the United States. Metal clad uranium oxide pellet fuel elements have been used in almost all pressurized water and boiling water reactors designed for civilian applications. Reprocessing techniques are well established. The system has lower operating temperature than the more advanced maritime gas-cooled reactor and calls for a shorter overall program. Our program will fully utilize results already achieved and to be achieved and to be achieved on program now going on. In turn, results achieved during our gas-steam project will assist other Atomic Energy Commission programs.

Our plan calls for the reactor system to be completed and ready for testing in a little under 3 years, and ready for sea trials in about 3½ years. Our estimates indicate a development cost of about $5 million, and construction and test cost of about $10 million. You will understand that these figures are being continuously refined as our project progresses.

Based on present estimates of net fuel costs, the nuclear fuel will be competitive with bunker fuel oil by the third or fourth core loading. In addition, our calculations show that the ships' cargo oil capacity will be increased by approximately 5 percent, largely offsetting the early fuel cost with greater payload.

All three of our organizations, Isbrandtsen, Maryland Shipbuilding, and the Ford Instrument Co. are convinced that this reactor system represents the most practical approach toward achieving advanced nuclear propulsion of merchant ships in the near future. Our three companies are now working together to achieve a nuclear-powered ship of advanced design at the earliest possible date. The first phase of the project is proceeding according to plan, and excellent progress has already been made.

Our group of companies declares its firm intention to aggressively pursue to its logical conclusion this program to put a nuclear-powered tanker in actual service in world trade. The support of the Government is of course necessary, since no company or group of companies can afford to bear the entire development and construction costs inherent in such a project.

Gentlemen, in order to provide our merchant marine with one of the important advantages it needs to regain its competitive position among maritime nations, we strongly urge the early passage of legislation that will enable projects of this nature to be carried out.

Chairman ANDERSON. Thank you, Mr. Rockwell; I am particularly happy with that statement, because in 1956 I testified before one of the committees—I think Senator Magnuson's committee—that it seemed to me that tankers had the best chance of becoming economically worthwhile in the maritime field, because they can be at sea 95 percent of the time, have very quick loading and unloading facilities, and I am glad to learn you have made this proposal.

On page 3 you say:

> Our company has been carrying out theoretical studies and experiments in civilian high temperature gas-cooled reactor field for a longer time than any other industrial firm in the United States.

Didn't you have a project at Holyoke, Mass., sometime ago?

Mr. ROCKWELL. Yes, sir.

Chairman ANDERSON. Was that public power for the city of Holyoke?

Mr. ROCKWELL. Yes.

Chairman ANDERSON. What happened?

Mr. ROCKWELL. This is covered in written testimony, Mr. Chairman, that we submitted for the 1957 hearings.

Chairman ANDERSON. Was it approved?

Mr. ROCKWELL. No, sir, it was not.

Chairman ANDERSON. You have had quite a bit of experience in this field. What caused the thing to bog down?

Mr. ROCKWELL. It was deemed at that time to contain too many advanced unknown elements which would require solution before it could work. That was a slightly different type of project.

Chairman ANDERSON. Yes, I understand it was gas-cooled.

Mr. ROCKWELL. Yes, with a closed cycle gas turbine.

Chairman ANDERSON. So the position of the Atomic Energy Commission was that it does not approve these advanced concepts until they have been tested. Was that it?

Mr. ROCKWELL. In this particular case, Mr. Chairman, the decision was that there were too many areas of advancement, that the state of the art had not progressed far enough in several different areas on the project.

Chairman ANDERSON. I am sure that you are acquainted with the general field. Was it relatively as advanced as the General Dynamics proposal that is now before the Commission and soon before the Congress, with which I am sure you are familiar? The General Dynamics proposal you will hear about a little later this morning is a sort of third stage to the Calder Hall reactor. It is a high temperature reactor. It involves a number of new theories that have not gone through a critical test.

Mr. ROCKWELL. I am not familiar with this project. I am sorry, Mr. Chairman. I have Mr. Jarvis, who is the manager of our Nuclear Development Division, who can pick up some of the technical aspects if you would like to talk about them.

Chairman ANDERSON. We would be happy to have him comment at any time. You are certainly familiar with the basic Calder Hall design.

Mr. JARVIS. Yes, sir.

Chairman ANDERSON. You are also familiar with the second stage which is the so-called Kaiser–ACF studies which were done in compliance with law of the Congress, toward the construction of a reactor.

Mr. JARVIS. Yes, sir.

Chairman ANDERSON. Then there is a third. I understand that the British are now starting to build one of those and there was a proposal that we build one here. There is a third proposal that General Dynamics and Philadelphia Electric Co. have now pending which the Atomic Energy Commission has announced it has decided to accept and approve, and ask Congress for authorization, which is the high temperature gas cooled reactor that is going to be discussed later this morning.

Was your Holyoke design more untried than the third Calder Hall stage, so-called, the high-temperature reactor?

Mr. JARVIS. Mr. Chairman, by the third stage, do you mean the British high-temperature gas cooled reactor, ceramic program?

Chairman ANDERSON. What I am referring to is the proposal which the Chairman of the Atomic Energy Commission referred to yesterday. It is a high temperature, with fuel elements originally to be metal clad. Dr. deHoffmann is here, and I hope he won't mind my defining what his project is. It will have temperatures running up into 800° F. and far beyond that eventually when the graphite cladding is available. But it is not a secret document, I am sure. The British have started some preliminary work along this line, and Dr. Fortesque from their Calder Hall plant has come over to this country to work with General Dynamics. Southern California Edison has sort of sponsored it for a while, and they dropped it, and in the last few weeks before the date when they had to do something about it, Philadelphia Electric picked it up. I thought there was quite a bit of discussion of it. I am not going to attempt to give you any technical analysis. I thought you might know what it was.

Mr. JARVIS. I am fairly familiar with the British third program that you described.

Chairman ANDERSON. That is the third program?

Mr. JARVIS. Yes. There has not been too much published in the open literature on the Philadelphia Electric plant. There has been a limited amount published in Nucleonics.

Chairman ANDERSON. They sent me five volumes. I will be glad to have you go through them. I enjoyed it. Some of it may be a little restricted for their competitors. I would not want to violate any of their trade secrets. I am sure that Dr. deHoffmann will give some explanation of it this morning when he testifies.

I was wondering whether that involved relatively more unproven theories than the one you proposed for Holyoke? Are they similar in any way?

Mr. JARVIS. Sir, the basic technology of the Holyoke reactor is quite different than that proposed for the Philadelphia Electric plant. The Holyoke reactor was based upon a stainless steel, uranium dioxide fuel element with graphite moderator.

Chairman ANDERSON. Yours is helium cooled. Theirs is helium cooled. Yours is graphite moderated. Theirs is graphite moderated. Yours is fueled with stainless steelclad uranium dioxide pellets. They are using uranium carbide.

Mr. JARVIS. There is a great deal of difference in that area. The fuel elements for our reactor will be clad externally.

Chairman ANDERSON. Is yours a little more conservative? It is more like the Kaiser–ACF.

Mr. JARVIS. I would describe it as close to the Kaiser-AFC design. The fuel elements will actually look very much like those of the blanket of the pressurized water reactors. Very much like the Yankee atomic energy plant. Very much like the Savannah.

Chairman ANDERSON. Is that true of the Holyoke concept that was turned down as being too advanced?

Mr. JARVIS. Yes, sir.

Representative HOSMER. Mr. Chairman, did you have pelletized fuel in the Holyoke reactor or metallic clad?

Mr. JARVIS. I am sorry, sir. By pellets we mean that the uranium dioxide is manufactured into pellets and inserted into metallic cladding.

Representative HOSMER. Is that the Holyoke concept?

Mr. JARVIS. Yes.

Representative HOSMER. And it is the same concept you planned for this one you described this morning?

Mr. JARVIS. Yes, sir.

Representative HOSMER. Whereas the General Dynamics plan is a homogeneous mixture of fuel and graphite?

Mr. JARVIS. Yes, sir.

Representative HOSMER. It differs somewhat basically.

Mr. JARVIS. Yes, sir.

Chairman ANDERSON. I was trying to find out if this design of yours is not somewhat more conservative. It has, in a way, been tested; has it not?

Mr. JARVIS. Yes, sir. We feel that our design is the most conservative, both with respect to materials and with respect to temperatures of any of the newer gas-cooled reactor programs.

Chairman ANDERSON. On page 6 you say:

Metal clad uranium oxide pellet fuel elements have been used in almost all pressurized and boiling water reactors designed for civilian applications.

Mr. JARVIS. Yes.

Chairman ANDERSON. I understand these metal clad uranium oxide pellet fueled elements were in the Holyoke design.

Mr. JARVIS. Something like it; yes, sir.

Chairman ANDERSON. Senator Pastore.

Senator PASTORE. No questions.

Chairman ANDERSON. Mr. Van Zandt.

Representative VAN ZANDT. Mr. Rockwell, in the morning mail I received a letter from a constituent asking me a few questions about the application of nuclear power to the propulsion of ships. Maybe you can be helpful. I am just going to ask you the first question. Is the propulsion of merchant ships or tankers by nuclear energy apt to become competitive with fossil fuel ships within 5 years?

Mr. ROCKWELL. We believe it will be competitive. It is doubtful that this will be within 5 years. Quite doubtful.

Representative VAN ZANDT. In other words, would you say 10 years?

Mr. ROCKWELL. I think this is reasonable.

Representative VAN ZANDT. The second question: What is your opinion on the British viewpoint regarding nuclear propulsion of ships for merchant application where they state that it is too costly. You have had contact with the British and their Calder Hall reactor. Can you answer that question?

Mr. JARVIS. I believe there is a consideration that prevails here that is not entirely apparent. When one designs a reactor for a ship, one is pretty much limited to the use of enriched fuel. We in the United States have the only enriched fuel available in large quantities at reasonable prices. So I believe our situation is not comparable with that of the British. In fact, it is our point that the atomic energy situation in the United States is the one unique potential advantage that we have over all other merchant marines.

Representative VAN ZANDT. We visited the British last fall, and in conversation with their Atomic Energy Authority, we were informed that they had turned thumbs down on nuclear-powered merchant ships. If my memory serves me correctly, they said it just could not be competitive with conventional type propulsion. When we got over into Geneva, we found quite an exhibit there in the industrial phase of the conference, and I was amused by the gentleman in charge of the exhibit when he produced an order book and he said, "We are just waiting for someone to give us an order."

We went back about a week later and I asked him if anyone had placed an order and he said "No, but we are still looking."

The next question: Is the United States making available financial assistance for fleet operators, any moneys for the development, study, or investigation of the application of nuclear energy to ship propulsion?

Mr. JARVIS. Not to my knowledge. Not in an organized way.

Representative VAN ZANDT. Not in an organized way?

Mr. JARVIS. Yes, sir. There may have been some money given to fleet operators for studies, but I don't know.

Representative VAN ZANDT. At the present time the only one we know of is the nuclear-powered ship *Savannah*.

Mr. JARVIS. Yes.

Representative VAN ZANDT. The next question: Are the political and social problems related to the operation of nuclear powerplants in international trade and commerce particularly in foreign ports, of sufficient magnitude to delay the advent of nuclear propulsion to large scale use, such as 10 years, or are these problems considered of only passing importance and of little effect upon the practical development of nuclear energy to ship propulsion?

The shipping company that you are identified with is in international trade.

Mr. JARVIS. Yes, sir.

Representative VAN ZANDT. I wonder if you can answer that question?

Mr. JARVIS. Yes, sir. I think, sir, there are two answers to it. One, there is underway an international effort among those nations of the world which are planning nuclear merchant marines to provide for uniform regulation, uniform standards of construction and operation of nuclear ships. So that is one element which I think will go a long way toward allaying any public fear.

A second element is that in our choice of a tanker we believe we may have bypassed the question because a tanker is a class of ship that does not normally come into a city harbor but picks up its cargo and discharges it at relatively remote locations.

Representative VAN ZANDT. It spends most of its time at sea.

Mr. JARVIS. Yes, sir. This ship in our mind will be a work ship, a ship designed to do useful work.

Representative VAN ZANDT. Thank you ever so much.

Chairman ANDERSON. Senator Aiken.

Senator AIKEN. Mr. Chairman, I cannot ask any questions relating to technicalities intelligently. Possibly a question related to practicalities might be admissible.

Mr. Rockwell, I noticed in mentioning the advantages of nuclear-powered merchant ships you particularly pointed out the possibility of carrying more cargo. Are there some other advantages that you anticipate? Do you anticipate any time saving? Would it be possible to get more speed out of the ships without completely changing the design? What about the cost of operating aside from the fuel itself?

Mr. ROCKWELL. The speed of these things does not increase very rapidly with increasing horsepower, so while you could, of course, build a ship-borne reactor with considerably more horsepower than we are specifying here, you would not get a parallel increase in speed. On top of this, tankers can fuel themselves very rapidly so that the savings here will come in the economies resulting from lowered fuel cost over those presently required for fossil fuels after experience in nuclear fuel costs have gone down somewhat. There will be a considerable saving in maintenance. For example, their type of a powerplant in a ship will be essentially a sealed engine room. You just do not have people monkeying around with a nuclear reactor at sea. So you will have to build the thing right in the first place, and there will not be any significant maintenance cost. Every 5 or 6 years you may have to pull the thing down and look over some of the machinery.

The 5 percent payload saving we have mentioned here, I should point out, is a 5 percent saving in this particular ship. Bear in mind we have left all of the power generating machinery which now exists in the SS *Hans Isbrandtsen* still aboard. This does not call for the removing of the present turbines, present steam boilers and burners and so forth. So the power saving in a ship designed around this kind of powerplant, that is the second generation, would have a much greater load-carrying capacity increase than this one. This is a 5 percent increase in the SS *Hans Isbrandtsen* achieved by taking enough storage capacity to make room for the reactor. But the weight saving, and the bulk space saving in the reactor and its power supply, even though we leave the original powerplant in there, is still estimated at at least 5 percent.

Senator AIKEN. After the first ship you would not contemplate leaving all of the conventional machinery in, would you?

Mr. ROCKWELL. No, sir. This is an actual working prototype of a design which we believe will be a practical thing to design into a ship after this has proved itself out. After this has been operational, and it is deemed as a reasonable ship propulsion technique, the next ship that was built would not be built with a complete oil burner steam boiler type system.

Senator AIKEN. After the first ship, and you left out the conventional machinery, then would the merchant ship operate with a smaller crew?

Mr. ROCKWELL. This gets into a difficult area for me to answer. We believe it could operate with a smaller crew. Whether as a practical matter it will be possible, this is hard to say. The railroads, I think, could have saved some crew.

Chairman ANDERSON. We are not going into any featherbedding practices at this time. If we stay on the nuclear end, we will be all right.

Senator AIKEN. I have no more questions, Mr. Chairman.

Chairman ANDERSON. Mr. Holifield.

Representative HOLIFIELD. No questions.

Chairman ANDERSON. Mr. Hosmer.

Representative HOSMER. This *Hans Isbrandtsen* class ship, what size is it?

Mr. ROCKWELL. It is approximately 33,000 tons.

Representative HOSMER. What is its size in relation to the T–4?

Mr. JARVIS. I am not familiar with the T–4.

Representative HOSMER. The standard tanker they were producing during World War II.

Mr. JARVIS. I believe that is the T–2. I think it is several times larger in dead weight ton capacity or in the amount of oil carried.

Representative HOSMER. Is Isbrandtsen running any regular tanker run at the present time?

Mr. JARVIS. Yes, sir, the *Hans Isbrandtsen* is in service at the present time.

Representative HOSMER. You have more tankers than this, haven't you?

Mr. JARVIS. I am not sure.

Representative HOSMER. Have you any economic studies in chart or table form on this propulsion?

Mr. JARVIS. We have certain studies made. These studies are continuously revised as better information is developed.

Representative HOSMER. These are nice conclusions in Mr. Rockwell's testimony, but if we had some tabulations for the record, it would probably give us a clearer picture.

Mr. ROCKWELL. You must understand this is a preliminary description of a plan which we have only been working on for a short period of time. The basic concept of the gas steam reactor, the jumboizing installation in the ship and the preliminary studies of fuel costs and operating costs indicate to us that after three or possibly four core loadings this will be economically sound. The initial phases of the whole program will be devoted to the study of the economics, of course. This is one of the keys to the whole program. We have this data in preliminary form. We have done much of this work. We do not have it available to present, but if the committee would like to have it, we would be very happy to send it down.

Representative HOSMER. Isn't it true that what might be an economical fuel cost on one route would be a highly uneconomical one on another route?

Mr. ROCKWELL. This is possible, surely.

Representative HOSMER. We are not to conclude that you are making any wholesale statement about this?

Mr. JARVIS. No, sir. Our statements are made with respect to the usual route followed by supertankers.

Representative HOSMER. What usual route? Between the gulf and the east coast or between South America and the east coast?

Mr. JARVIS. No, sir. The large supertankers are mostly used in routes such as from the Middle East to the east coast of the United States.

Representative HOSMER. It depends on the size of the tanker?

Mr. JARVIS. Yes, sir. That is the route on which the largest class of tankers are employed. That sort of a route.

Representative HOSMER. Would you give us an idea of how this reactor that you propose differs from that which is proposed for the *Savannah?*

Mr. JARVIS. Yes, sir. In the reactor the heat is transferred from the nuclear fission in the core to the boilers to generate steam by means of helium gas instead of pressurized water that transfers the heat from the nuclear core to the boilers in the *Savannah.*

Representative HOSMER. And your fuel elements differ?

Mr. JARVIS. The fuel elements would differ largely in geometry. Actually we would propose to use fuel elements which are quite similar to those in the *Savannah.* The changes would be in order to achieve better heat transfer for the gas.

Representative HOSMER. Is the *Savannah* going to use pelletized fuel also?

Mr. JARVIS. Yes, sir.

Representative HOSMER. What is the state of the art respecting the use of pelletized fuel today as compared with 2 years ago?

Mr. JARVIS. A great deal of work has been done on metal-clad uranium dioxide fuel in the past 2 years.

Representative HOSMER. Would you say that today the art is approaching a conventional as compared to being somewhat exotic 2 years ago?

Mr. JARVIS. It is a matter of words, but I would say it is approaching the conventional today certainly.

Representative HOSMER. I believe that is all.

Chairman ANDERSON. I have one final question. On page 7, you say the support of the Government is, of course, necessary. Have you taken this matter up with AEC?

Mr. ROCKWELL. No, sir. We have discussed the concept of the project somewhat. That is all.

Chairman ANDERSON. Not the question of support. They have an authorization bill up here now. If you are going to get the thing authorized, the committee has to have hearings upon it, and the Congress has to act upon it.

Mr. JARVIS. Yes, sir. This project has been discussed with the Maritime Reactors Branch of the Atomic Energy Commission.

Chairman ANDERSON. But the question of support on the other gas cooled that we are going to hear about in a minute, the Government will put in about $23 million out of $39 million. What is your cost on this?

Mr. JARVIS. Our very preliminary estimates are in the area of $15 million.

Chairman ANDERSON. You do not have any idea how much support you are going to ask from the Government for research and development and things of that nature?

Mr. JARVIS. Not today, sir.

Senator PASTORE. If the Senator will yield on that point, am I wrong in assuming or am I right in assuming that the type of project that we are talking about here is one that private industry cannot engage in exclusively on its own? It would need assistance from the Federal Government if ever we are going to have this, would it not? Isn't that the point you mean to make?

Mr. JARVIS. Exactly, sir.

Representative HOSMER. One other question, Mr. Chairman. On the $15 million cost that you mentioned that your companies would put in, is that the way it should be understood?

Mr. JARVIS. I believe the statement was that the project would cost about $15 million.

Representative HOSMER. Would you expect to write that off as an expense for tax purposes?

Mr. JARVIS. No, sir.

Mr. ROCKWELL. I think you misunderstood. Mr. Jarvis said that the project in toto would cost $15 million. We are looking for Government support on the project.

Chairman ANDERSON. Thank you very much.

Dr. deHoffmann.

STATEMENT OF DR. FREDERIC deHOFFMANN, VICE PRESIDENT AND DIVISION GENERAL MANAGER, GENERAL ATOMIC DIVISION, GENERAL DYNAMICS CORP.

Dr. DEHOFFMANN. Thank you, sir.

Chairman ANDERSON. We are glad to have you with us this morning, Dr. deHoffmann. You may proceed.

Dr. DEHOFFMANN. Thank you, Mr. Chairman, members of the committee. I have taken the liberty of bringing Dr. Thomas H. Pigford, assistant director of our laboratory, along so if you have any technical questions to which I cannot give you the answers, Dr. Pigford can supply them.

Thank you for your kind invitation this morning, and I am very pleased that one of the suggested topics on your program is that concerning nuclear maritime propulsion. We are happy that you have asked for testimony on this subject inasmuch as we in General Dynamics Corp. believe this program to be one of the most important programs in the entire nuclear energy field.

The maritime gas-cooled reactor program is being carried out by our corporation for the U.S. Atomic Energy Commission and the U.S. Maritime Administration. The incentives for economic nuclear propulsion are evident—one need only recall the large amounts of fuel a conventional ship must carry to propel itself. On the other hand, nuclear propulsion for commercial shipping purposes is clearly uninteresting unless we can demonstrably get no nuclear powerplants which compete on a firm basis with fossil fueled plants. Now at the end of its first year of design and development the MGCR program has made definite advances toward achieving this goal. I believe you will be interested in hearing about the progress of this MGCR program which has been underway for more than a year in our general atomic and electric boat division. The MGCR program is specifically directed toward a prototype for a ship such as a large oil tanker.

The MGCR system is a high temperature gas-cooled reactor coupled to a closed cycle gas turbine propulsion system. The program is, of course, undertaken within the framework of the broad objectives of the U.S. Atomic Energy Commission to expand and advance the technology of high temperature gas-cooled reactors as a class.

The MGCR system is, therefore, designed to couple an advanced reactor with an advanced propulsion system. Completion of the prototype is scheduled for May 1963, based on the rate at which the technical program should proceed.

The technological development of high temperature gas turbines over the past 15 years has led to today's capability of designing MGCR turbomachinery components of the necessary efficiency. Marrying this special power cycle to the high temperature gas-cooled reactor results in a true direct cycle gas system with only one working fluid. The result is a compact, safe, simple, and lightweight propulsion plant with thermal efficiencies as high as 32 percent and higher. The reactor is graphite moderated and cooled with helium. The reactor is to be fueled with enriched uranium dispersed in a ceramic and embodied as a heterogeneous fuel assembly. An alternative approach now under test embodies a semihomogeneous element which materially increases the plant performance and safety and simplifies its design.

The MGCR system offers high efficiencies under a wide range of load conditions. Exceptional inherent safety, of special importance to maritime application, results from the low stored energy and low induced radioactivity in the gas coolant, and from the possibility of utilizing the large heat capacity of the graphite moderator. Rela-

tively little secondary shielding is required, and the coolant is inert to radiation effects.

The MGCR will have the inherent flexibility of the closed cycle gas turbine in making rapid, thermal stress free power changes resulting in good maneuverability. All these characteristics make the MGCR system particularly well suited to marine applications.

It should, of course, be clearly recognized that this is by no means the first closed cycle gas turbine powerplant. In fact, conventionally fired closed cycle gas turbine systems have been operated in Europe. Such conventionally fired plants are now being constructed for land based, as well as one marine application in several parts of Europe, Russia and in Japan. The MGCR will develop a system of even higher performance by marrying this technology to a nuclear heat source.

The high performance MGCR system calls for the development of new technology and, therefore, requires an experimental prototype rather than an operational shipboard units as the first plant. Development of the turbomachinery is being carried out by Westinghouse under subcontract. Extensive materials tests for the reactor and turbomachinery are now underway and engineering development and experimental work on these and other plant components is proceeding. The large MGCR inpile loop will be completed shortly and will further extend our fuel testing program. The program is moving ahead on hardware and is projected toward initiation of detailed design and fabrication of certain long lead equipment items later this year.

Until the MGCR plant has been fully designed, built and tested as a prototype, it is difficult to make a precise quantitative comparison between it and conventional and other maritime nuclear propulsion systems. However, there are certain very obvious advantages of the gas-cooled system over others presently being considered for maritime application:

1. The MGCR-propelled tanker requires substantially less machinery space than other systems, and for the purpose of comparison, would use only about two-thirds the space presently taken up by the powerplant in the *Savannah*.

2. The weight of the powerplant is substantially less than that of other systems. We estimate that an MGCR powerplant weighs less than two-thirds as much per shaft horsepower and about half per unit of cargo as that of the *Savannah*.

3. The MGCR thermal efficiency of 32 percent is better than that of the conventional marine propulsion systems and also is considerably better than that of any nuclear propulsion system currently under design for conventional shipping use. This relatively high efficiency extends to part load conditions, an advantage not found in steam cycle systems.

4. The MGCR system is especially well suited to exploiting expected technological advances for incorporation into subsequent plants. An advanced gas-cooled system with cycle efficiencies as high as 40 percent is a logical extension of the MGCR.

The general design characteristics of the MGCR and the results leading up to it are contained in an appendix to my testimony which, with your permission, I would like to file for the record.

(The appendix referred to follows:)

APPENDIX

PREPARED BY THE MARITIME GAS-COOLED REACTOR PROGRAM STAFF GENERAL, DYNAMICS CORP.

Background

The maritime gas-cooled reactor program was initiated on February 17, 1958, as a contract between General Dynamics Corp. and the U.S. Atomic Energy Commission-Maritime Administration. The program objectives are to develop and construct a land-based prototype of a high-temperature nuclear reactor coupled with a closed-cycle gas-turbine system for maritime application. The overall project responsibility is assigned to the General Atomic Division of General Dynamics and the project is carried out by a staff of technical personnel assigned from the General Atomic and Electric Boat Divisions. Westinghouse Electric Corp. is subcontractor to General Dynamics for the development of turbomachinery for the project.

The MGCR program had been anticipated as early as midyear 1956. Two Commission contractors had just completed feasibility studies on the application of gas-cooled reactors to civilian usage. Both studies indicated gas cooling was promising but that large advances in the existing knowledge were required. Based on the results of these studies and other factors, three additional feasibility studies were completed by AEC contractors in the spring of 1957. Each concluded that considerable development is required on both the reactor and the closed-cycle gas-turbine cycle. However, when developed, the system will be a high performance, competitive, compact system.

On this background, the present MGCR program was initiated. The specific objective is to develop, design, build and test a prototype gas-cooled reactor closed-cycle gas-turbine powerplant for a maritime application. However, the program has the broader objective to expand and advance the technology of gas-cooled systems and components, particularly in the temperature range above 1,300° F.

The thermodynamic potential of the closed-cycle gas-turbine powerplant has been well recognized for many years. Early attempts to utilize this potential, however, were unsuccessful because of poor component efficiencies. The technical development of high-temperature gas turbines over the past 15 years has led to the capability to design components with the necessary efficiency. Marrying this special power cycle to the high-temperature gas-cooled reactor results in a true direct-cycle gas system with one coolant-working fluid and results in a compact, simple and light weight powerplant. The MGCR program is to develop the new high performance reactor and the special turbomachinery for this application and to combine them into a workable, reliable, operational prototype plant embodying this technology.

MGCR plant summary

The principal performance parameters of the MGCR prototype plant are shown in figure 1.

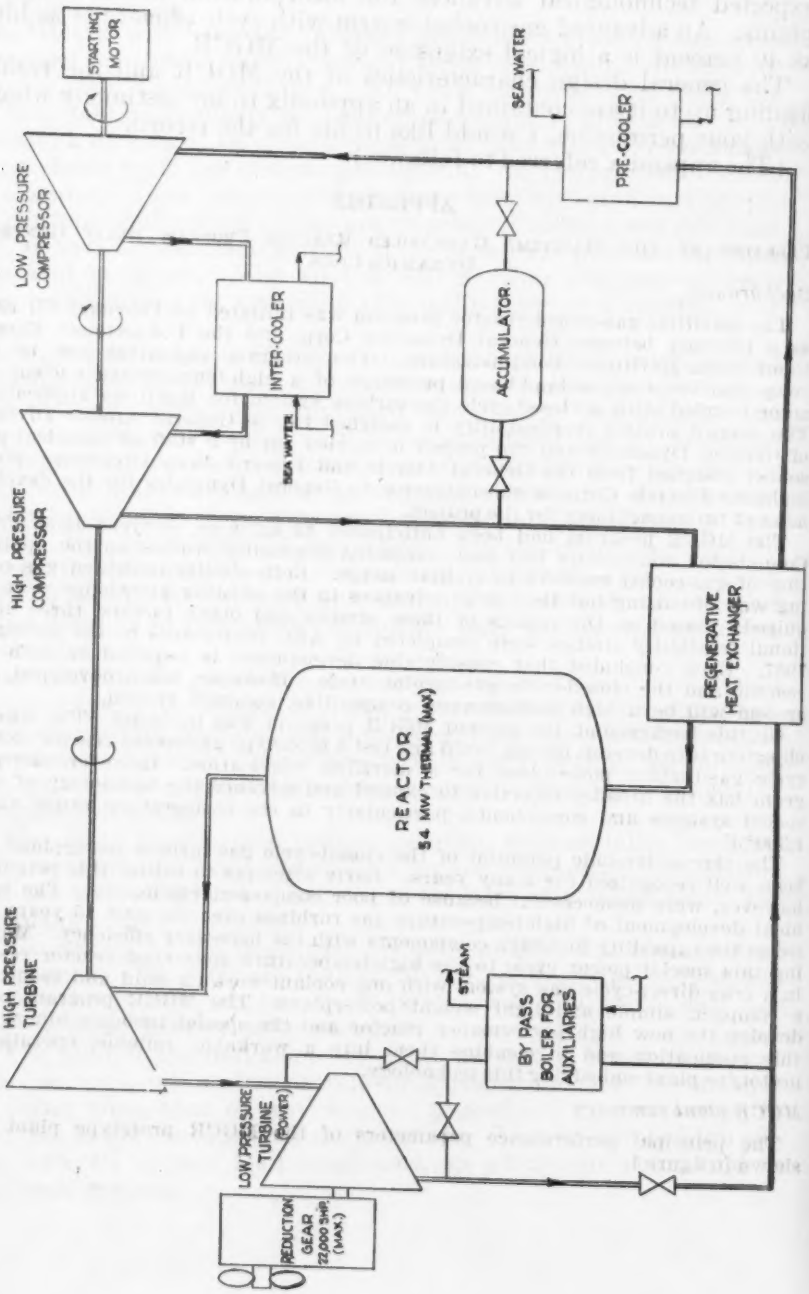


FIGURE 1.—MGCR MAIN PROPULSION SYSTEM PROCESS FLOW SHEET

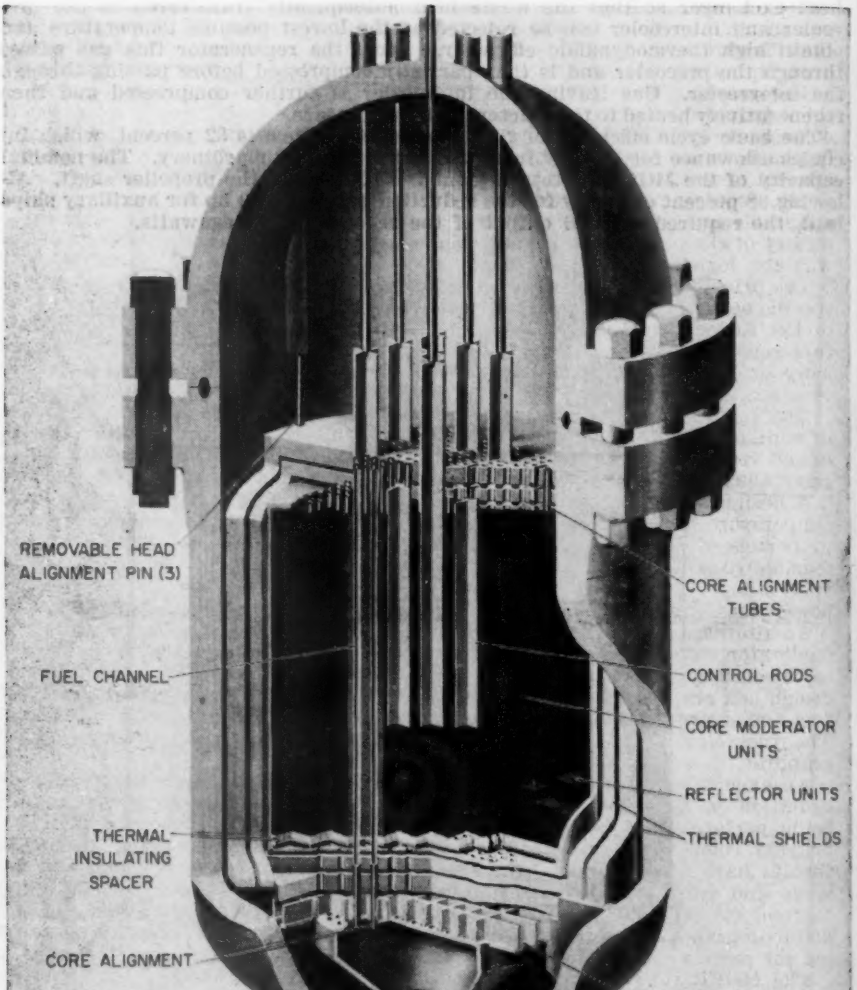
The graphite-moderated reactor heats helium gas to an outlet temperature of 1,300° F. or greater. The hot outlet gas then expands through the high pressure turbine which drives the compressors. It then undergoes further expansion through the low pressure turbine which drives the propeller through a reduction gear. After leaving the low pressure turbine, the gas is cooled in a regenerative heat exchanger so that the waste heat subsequently transferred in the precooler and intercooler can be rejected at the lowest possible temperature and obtain high thermodynamic efficiency. From the regenerator this gas passes through the precooler and is then partially compressed before passing through the intercooler. Gas leaving the intercooler is further compressed and then regeneratively heated to the reactor inlet temperature.

The basic cycle efficiency of this closed-cycle system is 32 percent, which includes allowance for entropy increases in the rotating machinery. The nominal capacity of the MGCR prototype plant is 20,000 hp at the propeller shaft. Allowing 98 percent efficiency for the reduction gear and 750 hp for auxiliary ships load, the required thermal output of the reactor is 54 megawatts.

Reactor design

A schematic diagram of the MGCR reactor is shown in figure 2.

FIGURE 2.—CROSS-SECTION VIEW OF REACTOR



The helium coolant enters the reactor vessel through the outer annulus of the concentric-duct piping at the bottom of the vessel. The gas then flows up, outside the reflector, and enters the core from the top. As it passes up outside the reflector it cools the thermal shields and vessel wall and maintains them near the temperature of the inlet gas. The flow is orificed at the inlet end to maintain essentially constant outlet temperature from each fuel channel. The gas then flows along the surfaces of the fuel assemblies. The hot outlet gas then flows out of the pressure vessel through the inner duct of the concentric-duct piping and thence to the high-pressure turbine.

The graphite core is 6.4 feet in diameter and is surrounded by a 1-foot thick graphite reflector. The principal considerations that led to the selection of graphite as moderator were the safety features, as described later, and the emphasis on structural simplicity of the reactor core. Although not the most efficient neutron moderator, graphite has good high-temperature materials properties, requires no special cooling for moderator temperature control, and is adaptable to a relatively simple structural design. Further, to avoid the complexity of cladding or cooling the graphite to protect it from the coolant, helium was the logical choice as coolant.

The principal problem to be solved in any gas-cooled reactor operating at high specific power and high temperature is that of the fuel element. Two approaches to the fuel element problem are the heterogeneous assembly, e.g., bundles of fuel rods, and the semihomogeneous element in which the fuel is dispersed more or less uniformly in solid blocks of graphite moderator. Each has its own special features and problems, as summarized below.

The rod bundle element is a cartridge of 19 rods of 0.25-inch diameter clad in stainless steel. The rod bundles are encased in a graphite cylinder and positioned vertically within holes in the graphite core. At MGCR design conditions about 350 such fuel bundles are required.

A design steady power temperature limitation of 1,500° F. maximum surface temperature has been selected for this fuel element based upon the mechanical properties of stainless steel. With helium as coolant at 800 p.s.i., it appears feasible to obtain exit gas temperatures of 1,300° F. in this design. Resulting maximum oxide temperatures are comparable to those existing in typical high-power density water-cooled reactors.

An alternate approach has been initiated on a semi-homogeneous graphite fuel-moderator element, which has sufficient heat capacity associated with the fuel to be relatively insensitive to accidental changes in coolant flow. The alternate design is a graphite plate-type element. Metal tubes containing uranium-bearing fuel bodies are inserted in close fitting holes drilled through the graphite plates. The fuel element is cooled by gas flowing along the outer surfaces of the graphite.

An experimental program on fuel and moderator materials is underway. Irradiation on UO_2BeO fuel bodies for the heterogeneous fuel assembly are now being performed. Construction of a large-scale in-pile loop for the MGCR is nearing completion, and test fuel assemblies are being prepared. Definitive results have already been obtained on graphite-metal carburization, and test loops and equipment for determining problems of heat-transfer performance, thermal cycling, and helium purification are being put into operation. The reactor program is rapidly approaching the hardware stage on many items including the reactor vessel and control drives.

The MGCR turbomachinery draws upon technology developed for industrial gas-turbine machinery as well as aircraft jet-engine experience. Designing such machinery for helium requires departures from this experience in mechanical detail. The aerodynamic problems of the helium machinery are relatively simple. A diagram of the turbomachinery now under development is shown in figure 3. As compared with conventional equipment, the helium turbomachinery requires more stages, has new materials problems, and has new problems of mechanical construction, seals, and bearings.

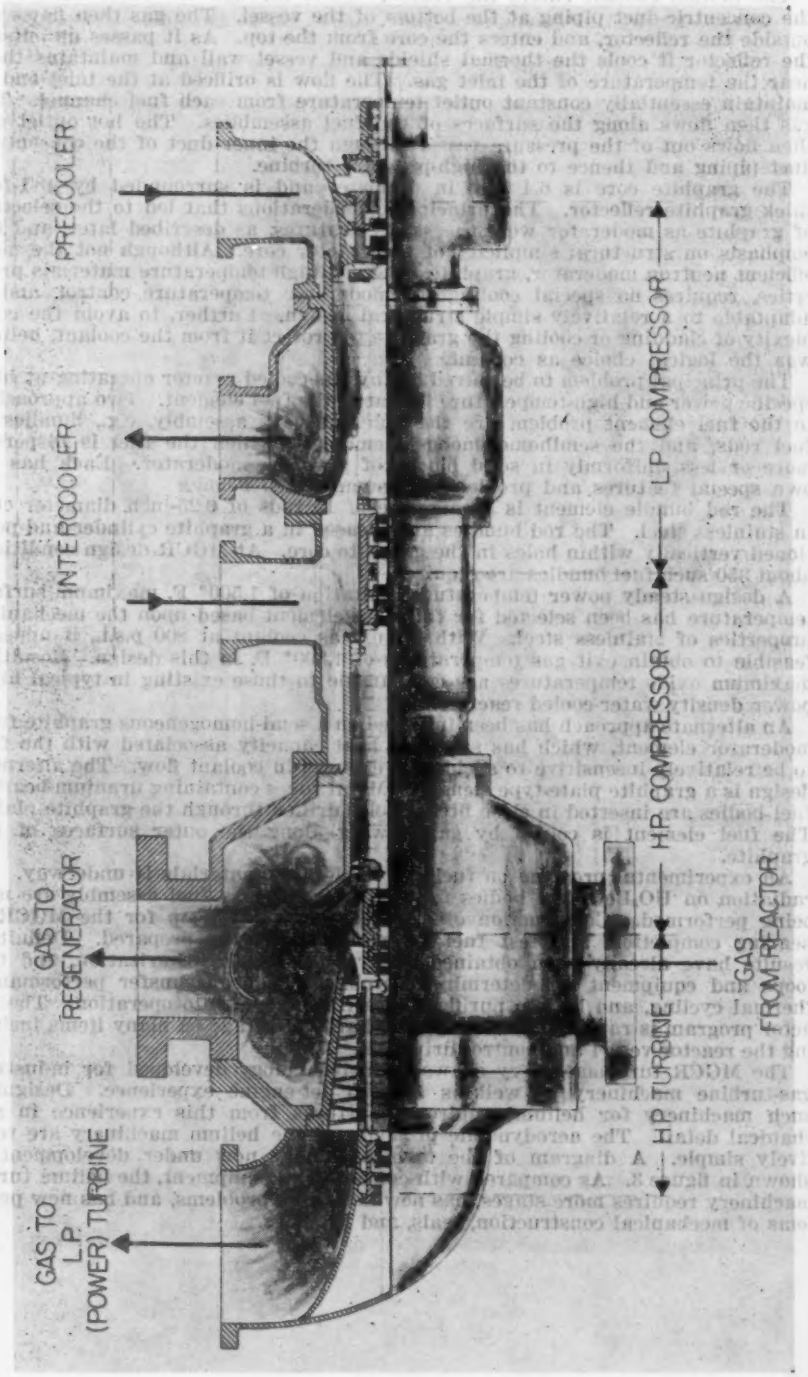


FIGURE 3.—MGCR ROTATING MACHINERY

Tests are beginning this month on a full-size seal and bearing test rig. Tests are underway to determine the properties of special high-strength materials to be used in the turbomachinery, and a development program is underway which will soon culminate in full-scale test models of the compressors and turbines.

The piping, valves, and heat exchangers for the MGCR all require some new design. Testing of heat exchanger sections is now underway, and work on valve development is being initiated.

Safety

In selecting the design for the MGCR system, special emphasis was placed upon safety. The principal safety features are:

1. The gas coolant carries relatively little stored energy.
2. Low induced activity is present in the helium.
3. Helium will not react chemically with fuel, moderator, and other reactor and powerplant materials.
4. The graphite moderator is capable of absorbing much of the nuclear afterheat, thereby simplifying the problem of emergency cooling. This particular feature will be most fully exploited if tests on the semihomogeneous element are successful and this element is adopted for the prototype.

Prototype size and flexibility

Since the MGCR powerplant represents an extension of technology in both reactors and turbomachinery, it is desirable to build an experimental prototype rather than an operational unit. In this way the systems can be designed to permit easy access for experimentation free from interference by operational requirements. This adaptability of the reactor, together with the flexibility of the closed gas turbine cycle, will permit the prototype plant to be used as a facility for testing future developments in fuel elements aimed at obtaining higher cycle efficiencies and better neutron economy. Hence, a land-based prototype is considered preferable to a shipboard installation for the first MGCR plant.

The 22,000 (maximum) shaft horsepower rating for the prototype powerplant is in the range of power levels expected to achieve economically interesting service. It also calls for turbomachinery whose physical dimensions are about as small as feasible for rugged machinery of high efficiency. Lower power levels may be obtained by operation at lower cycle pressures. Future plants of higher power ratings can be easily extrapolated from a plant of this size. Thus, at this power level, the reactor, machinery, plumbing, and other hardware are at the size required to establish reliability before such a plant is installed aboard ship.

Summary of plant data

A summary of the principal design parameters of the MGCR prototype is given below.

Power:	
At propeller shaft	22,000 horsepower (maximum).
Reactor, megawatts (thermal)	54 (maximum).
Auxiliaries	750 horsepower.
Net shaft efficiency	30 percent.
Cycle efficiency	32 percent.
Reactor:	
Moderator and reflector	Graphite.
Core (active lattice):	
Diameter	6.4 feet.
Height	6.4 feet.
Reflector thickness	1 foot.
Vessel:	
O.D	10.4 feet.
Height	25.5 feet.
Wall thickness	5.75 inches.
Fuel	Enriched uranium 128 kilograms U^{235}.
Fuel element:	
Heterogeneous	19-rod bundle, ¼-inch rods of UO_2 in BeO, stainless steel clad.
Semihomogeneous	Graphite flat plates 1 inch thick, 6 inches wide, 6.4 feet long, contain metal-clad rods of UC in graphite or UO_2 in BeO.
Fuel loading	Uniform.
Number of control rods	16.
Core life (at full power)	500 days (approximately).
Coolant	Helium.
Coolant pressure	800 p.s.i. from high power compressor. 308 p.s.i. into low power compressor.
Reactor inlet temperature	726° F.
Reactor outlet temperature	1,300° F.
Turbomachinery:	
Turbo-compressor speed	13,450 r.p.m.
Power-turbine speed	8,000 r.p.m.
Axial-flow stages:	
High-pressure turbine	7.
Low-pressure (power) turbine	6.
Low-pressure compressor	15.
High-pressure compressor	19.
Overall length	30 feet.
Shielding:	
Primary	40 inches of lead, iron, and water.
Secondary (integral with containment).	3 inches iron; 24 inches fuel oil (for emergency diesel powerplant).
Plant weight (includes containment and auxiliaries).	2,020 long tons; 206 pounds per shaft horsepower.

Dr. DEHOFFMANN. Some economic analysis of this system and its application to oil-carrying tanker ships has been made. While the first generation of seagoing MGCR powered tankers is expected to have definite weight and space and thermal efficiency advantages over today's conventionally fired tanker ships, its overall economics may not compete with today's most advanced conventionally fired ships.

However, second generation ships show the following favorable situation: Consider, for example, a second generation tanker of 27,500 shaft horsepower, a deadweight tonnage of 60,000 and a speed of 18 knots operating between New York City and Kuwait in the Persian Gulf. This MGCR tanker would then show about 10 percent less costs per ton of cargo than present day costs of conventional shipping.

Chairman ANDERSON. Would that also apply to shipments going to Great Britain from Kuwait?

Dr. DEHOFFMANN. May I ask Dr. Pigford to reply to this?

Dr. PIGFORD. We have not analyzed that particular route, sir. It would depend mainly upon the differences in mileage, and I am not aware of the magnitude.

Chairman ANDERSON. Where does the Kuwait oil go?

Dr. PIGFORD. The Kuwait oil, as analyzed under this route, is brought back to the east coast near New York.

Chairman ANDERSON. Maybe you did not understand the question. I am trying to find out where the great volume of Kuwait oil goes. Does it come to this country?

Dr. PIGFORD. I do not know the answer to your question, sir.

Chairman ANDERSON. Venezuelan oil comes in here. Why don't we compare Venezuela and New York.

Dr. PIGFORD. This is a typical route that has been suggested to us by the AEC for comparison. There are others. This is the one which we have selected for the economic comparison here.

Dr. DEHOFFMANN. As you can see, the MGCR, by developing its gas cooled reactor especially designed for maritime application and marrying it to closed cycle gas turbine equipment, will give the United States a lead position in this new powerplant area.

Another one of your suggested topics dealt with the U.S. land-based power program. Inasmuch as your committee was kind enough to devote a recent Saturday morning in executive session to the subject of our HTGR central station nuclear power system, which has been under intensive development at General Atomic Division for the past 2 years, I shall not impose on your time on this subject at this hearing. Furthermore, your committee has now before it the proposal of the Philadelphia Electric Co. and 51 other utility companies who are members of High Temperature Reactor Development Associates to construct such a reactor with Bechtel Corp. and with the financial assistance of the U.S. Government. I would like to take this opportunity, however, to point out that both systems utilize the special benefits that can be achieved with high temperature gas cooling, but each in its own special way. Remember that the seagoing and the land-based reactor systems need to serve two quite different applications. The maritime system places special emphasis on ruggedness, safety, overall plant compactness and weight saving. The land based system must place principal emphasis on low resulting electricity costs achieved by means of low capital and low fuel costs. While both systems benefit by the use of graphite moderator and the use of helium as a coolant, the plant components and the plumbing and hardware do, in fact, differ in detail. Technology and equipment developed from both of these programs will be of great benefit to the country's nuclear power and nuclear propulsion programs.

Representative VAN ZANDT. What is your understanding, Doctor, as to the status of the Philadelphia proposal?

Dr. DEHOFFMANN. As I understand it, we have submitted, or rather Philadelphia Electric has submitted a proposal to the Atomic Energy Commission. As of this moment we have not been informed by the AEC. I understand in yesterday's testimony this was referred to. In other words, my information comes quite frankly from the state-

ments made here yesterday that have been told to me—that Mr. McCone, I believe, stated to you that the Commission was considering—I don't know what words he used, therefore I am in some difficulty and I do not want to quote words that have only been secondhand. I believe he stated that the Commission would like to accept this proposal as a basis for negotiating a contract. This is as we know the situation to be at the moment.

Chairman ANDERSON. May I give you the words? [Reading:]

We propose to accept the Philadelphia Electric Co.'s proposal to build a high-temperature gas-cooled reactor of about 40 megawatts. We will support this project with research and development assistance. I emphasize that this is a courageous step forward for both the Commission and industry.

Dr. DEHOFFMANN. Thank you, Mr. Chairman.

Representative VAN ZANDT. This is the information that has been furnished the committee members. I read here from a committee memorandum:

The Commission is rejecting the Philadelphia Electric-General Dynamics proposal as not conforming to the AEC authorization law for fiscal 1959.

Chairman ANDERSON. That is also in Mr. McCone's testimony.

Representative VAN ZANDT. That is right. [Reading:]

However, the Commission plans to submit this project for special authorization presumably in the same manner as the Florida project and the Pennsylvania Power & Light project of last year.

So the committee, I understand, will soon or probably has already received a legislative request from AEC. That is all, Mr. Chairman.

I might add that it is in the proposed bill, section 112.

Dr. DEHOFFMANN. Thank you, sir. Shall I proceed, Mr. Chairman?

Chairman ANDERSON. Surely.

Dr. DEHOFFMANN. Let me turn briefly now to another subject which I believe is of great importance in terms of the maximum utilization of the country's resources. This is the interrelation of research and development and the production of actual hardware items. Traditionally it has been industry's role to produce the hardware. I believe it is essential in the new nuclear field that industry fully understand the products it makes to achieve a high rate of productivity. A good nuclear hardware product can only be made when those making it have participated in enough of the research and development effort associated with it. There can be no abrupt transition from research to development or from development to production. There is much less distinction between research on the one hand and development on the other hand than there is between good and bad research and development. In our General Atomic Division we have, therefore, tried to embrace the whole spectrum of research, development, and production and believe that good research and development in the fission power field carried out right within the industrial complex will, in fact, enable us more surely to produce better and cheaper products for the national economy. This then has been the guiding principle behind both our MGCR and HTGR programs.

Other programs of General Atomic Division have carried out the same philosophy—one of them is our fusion program, the other our TRIGA program where this approach was proved out from inception through hardware.

In the fusion field we believe that the practical hardware stage is many years away. Nevertheless, as you know, we joined some time ago with the Texas Atomic Energy Research Foundation, consisting of 11 utility companies operating in Texas, to carry forward 4-year $10 million program in the field of controlled thermonuclear reactions. Theoretical work has been completed under this program dealing with the stability of the pinch. The past year has seen the completion of a special fusion laboratory at General Atomic, the completion of two pinch-type devices and the initiation of experiments leading to a fuller understanding of the pinch mechanism. In particular, the sudden energy loss occurring when such pinch effects take place which lead to the shutting off of the desired reaction, have bedeviled much of the fusion work in the world today. The program is now directed toward understanding the mechanisms that cause these energy loses, in order to find ways and means of preventing this loss.

The TRIGA programs previously referred to has, during 1958, reached the completed hardware stage. Conceived by General Dynamics, this novel uranium-zirconium hydride inherently safe research reactor system is now being installed on five of the six continents. It is generally recognized as one of the very few new reactor systems that has been conceived and brought to completion, and as such represents a significant advance in the reactor field.

I should say one of the few new reactor systems that has been conceived and brought into completion in the last few years.

Its special safety characteristics have been conclusively demonstrated in transient tests which have taken it to instantaneous power levels of 250,000 kilowatts.

Because of TRIGA's inherent safety and simplicity, it may help to accelerate the medical and industrial uses of atomic energy in a significant way.

We have been pleased to participate in the AEC's radioisotope program through our interest in providing isotopes of high specific activity from those made in a reactor of, say, 100 kilowatts power. In particular, techniques have been developed at General Dynamics to enhance the specific activity of sodium, chlorine, manganese, and other elements by hundredfold through the use of radiochemical concentration techniques. While the interest in these particular elements was stimulated by medical uses, we believe that eventually there will be a large use for short-lived radioisotopes in process industries, supplied by safe isotope production reactors located on the spot.

Perhaps one of the most significant uses of reactors in industry may be as a tool for process control and analysis. One application is an activation analysis by which a small sample is inserted in the reactor for a short time and the radioactivity provides the desired chemical analysis. During the past year, increased emphasis on this subject in the United States has produced very encouraging results.

Another program which we believe holds long-range promise is the application of direct conversion of high temperature nuclear heat into electricity. In our own company this thermoelectric work has been carried out with the cooperation and support of the Rocky Mountain Pacific nuclear research group of utilities.

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In closing, let me say that the encouraging results of the programs in atomic energy in which our company has participated during the past year make me feel even more certain that the importance of atomic energy in all its aspects to our Nation is developing at an ever-increasing rate.

Thank you very much.

Chairman ANDERSON. Doctor, this work on the maritime gas-cooled reactor is being carried out on a contract between the Atomic Energy Commission and the Maritime Administration?

Dr. DEHOFFMANN. It is being jointly funded by the U.S. Atomic Energy Commission and the Maritime Administration under contract with General Dynamics Corp., that is correct, sir.

Chairman ANDERSON. How was General Dynamics selected?

Dr. DEHOFFMANN. Very early in the formation of General Atomic Division, we carried out studies on maritime propulsion, since this was of considerable interest to us, and we were then selected as one of several companies to carry out a preliminary study for the Government to find out what a good system in this field might be. As a result of some of these studies, the Government decided that it would authorize a maritime gas-cooled reactor program and asked for proposals to carry out this work and bring a prototype to completion.

There were, I believe, about 18 companies which bid on this program, and we were selected to carry the program forward, and have been very happy to be able to do so for the Government.

Chairman ANDERSON. Was there a selection board that did this?

Dr. DEHOFFMANN. Yes, sir; there was a selection board that formally selected us over several months' selection.

Chairman ANDERSON. Who picked the selection board?

Dr. DEHOFFMANN. I believe that this selection board was a joint selection board of the Maritime Commission and the U.S. Atomic Energy Commission. I cannot recall the exact members of the board, but perhaps Dr. Pigford can.

Dr. PIGFORD. No.

Chairman ANDERSON. Does this contract give you access to the Rover project, Pluto project, and ANP programs?

Dr. DEHOFFMANN. The situation is that a limited number of personnel through the AEC branch in charge of the dissemination of that particular information have authorized—and this number is of the order of 8 or 10 people, I don't remember the exact number—access to categories C–84 and C–86. I would like to turn to Dr. Pigford as to whether the specific programs you have mentioned, access has actually been authorized.

Chairman ANDERSON. You know the reason that I raise the question. When I raised it in the excutive hearing, the statement was made that this contract at Los Alamos was made under the access program.

Dr. DEHOFFMANN. Thank you very much for bringing this up, Mr. Chairman. I think in the executive hearings I was just plain under a wrong apprehension, and I would be very happy to explain how this wrong apprehension came about. "Apprehension" is the wrong word. Under the wrong impression. When the management of General Atomic authorized the visit at Los Alamos of about four of our metallurgists, we were under the impression that we were giving our blessing to an exchange of information under the access program. Actu-

ally the visit had been preceded by an exchange of letters between Dr. Gurinsky working at our place, and Dr. Baker at Los Alamos, in which Dr. Gurinsky actually stated to Dr. Baker that a visit was requested to discuss two separate programs, namely, the program of the HTGR and the program of the maritime gas-cooled reactor. Neither Dr. Pigford nor I were aware that the maritime gas-cooled reactor program was involved, and therefore made such strong statements that we though they had not gone under the MGCR program.

On subsequently checking on returning home, as I had a chance to immediately report to you, Mr. Chairman, we found that in fact the control form that went out from General Dynamics Corp. to Los Alamos, indeed, in line with this letter, requested that they be given permission to discuss both these subjects. The people who went up there were not, however, cleared for C–84 or C–86 information. There was no request that went forward saying under the maritime program please give access to C–84 and C–86, and these four people were not authorized access to it.

Chairman ANDERSON. We are trying to check. The AEC records show that eight representatives of General Dynamics, including Dr. Pigford, since April 16, 1958, have had direct access to all Rover, Pluto, and ANP information in categories C–84 and C–86.

Dr. PIGFORD. Sir, I must be careful of my statements but we checked this one, and to our knowledge the MGCR project personnel have not yet received access to Project Rover under category C–86.

Chairman ANDERSON. This was graphite work that very definitely affected the Philadelphia Electric project. Los Alamos had finished a very fine contribution along that line and almost before they had a chance to report it to the laboratory director here came General Dynamics and wanted to know how they got it done. That is why I am curious about it.

Dr. DEHOFFMANN. May I comment on that, Mr. Chairman?

Chairman ANDERSON. Yes.

Dr. DEHOFFMANN. I believe you will find that our situation was the following. At the time the visit was made, which was November 13 and 14, the proposal was well formulated, well underway. In other words, the original work on which this proposal was based, as you know, goes back to almost 2 years and about a million and a half dollars worth of effort by General Atomic into this program.

Representative VAN ZANDT. You are talking about the Philadelphia program.

Dr. DEHOFFMANN. I am talking about the things that we had done to get us ready to the stage of being able to make a proposal to any group to build a reactor of this kind. During the course of this work we asked our people, as good scientific practice, to try to discuss any information freely available on graphite work and to exchange such information. On returning I checked carefully and I believe you will find that the information did not in any way affect the proposal because the proposal at that point was being put to bed in Philadelphia, where it was being physically prepared.

You will further find that it did not affect the design of this reactor in any way. So this is the actual situation.

Chairman ANDERSON. As far as the metal cladding is concerned, it has quite an implication.

Dr. DEHOFFMANN. It is also true as far as the other is concerned, Mr. Chairman.

Chairman ANDERSON. The witness just ahead of you said:

> Our company has been carrying out theoretical studies and experiments in the civilian high temperature gas cooled reactor field for a longer time than any other industrial firm in the United States.

Did they have a chance to bid on this job, do you know?

Dr. DEHOFFMANN. In Phlidelphia, you mean?

Chairman ANDERSON. No; on this job where you got this contract on the maritime work.

Dr. DEHOFFMANN. I am informed that the answer is "Yes," sir.

Chairman ANDERSON. Now you refer to this project you have joined in with Philadelphia Electric. The request for an authorization bill which the Commission has submitted to the Joint Committee calls for $14.5 million for your advanced high temperature gas cooled power reactor, and cuts off $20 million from the congressional authorization for a gas cooled reactor. Would you attempt to explain why that would happen?

Dr. DEHOFFMANN. I shall be very glad to, sir.

Chairman ANDERSON. There was $51 million provided by the Congress, which now is being reduced to $30 million, and $14.5 million will be made available to General Dynamics and Philadelphia Electric.

Dr. DEHOFFMANN. Our proposal to the Commission had only discussed the question of building this particular reactor. In fact, our knowledge of the ACF–Kaiser system, which is being referred to in your statement, is that of, I would say, knowledgeable and interested outsiders. But we have in no way discussed with the Commission this program. We have in no way participated or talked with them about what would happen about this project. Therefore, it quite frankly came as news to me yesterday that this would be $30 million rather than $51 million. In other words, I simply know no more on the subject, Mr. Chairman, than the statements you have just made.

Chairman ANDERSON. Do you regard this proposal of yours as supplanting the idea of constructing a gas cooled reactor of the Calder Hall advanced type?

Dr. DEHOFFMANN. No; I do not. I think that these two reactor systems, each in their own right, have different objectives in mind; except in the sense that they have the common objective of producing cheap electricity and cheap power. I do not regard them as one supplanting the other, sir. We have only looked upon our system as one worthy of being built and hoping to get the support between utilities and the Government to get it on the road and hope to do the best job we can to prove it out, and hope we can make some contribution thereby.

Chairman ANDERSON. I am happy to have you say that because it seemed to me that the effect—I am not talking about the purpose—of the authorization bill, if carried out, would be to make sure that General Dynamics was the only one in the business. The testing of an advanced type Calder Hall reactor which Britain itself has not yet built might offer some opportunity to learn something. Surely it would give us the rest of the information we thought we were going to get when we exchanged the secrets of the *Nautilus*, and have not yet obtained in full. I think I have no further questions.

Mr. Van Zandt?

Representative VAN ZANDT. I have no questions, Mr. Chairman.

Chairman ANDERSON. Mr. Holifield?

Representative HOLIFIELD. I have no further questions. When we get to the authorization bill and consideration of the line items, I want to go into the matter in some detail, but not here.

Chairman ANDERSON. I am sure that we all have that feeling. The authorization hearings will start about the 24th.

Mr. Hosmer?

Representative HOSMER. Doctor, as a scientific man, I think you can enlarge very much on your opinion of the relative merits of the advanced gas cooled reactor of the Calder Hall reactor and this concept you have. I don't want to embarrass you, but I would like to get on the record something of the relative merits of the two in relation to the fact that if you were putting the money up out of your own pocket which one would you buy?

Dr. DEHOFFMANN. Without going into the technical details—again I should emphasize that I have not studied the technical details of the advanced Calder Hall type proposal and in that sense I am talking off the top of my head—I think these two systems have a different approach to the problem. The system that is being suggested by General Dynamics Corp. is a system which, because it uses enriched fuel, say higher than 20 percent, is able to carry out certain steps toward compactness, toward very high temperatures, toward an eventual development. In that sense this gives it in my mind a considerable edge for eventual cheap power production, provided you accept the necessity for enriched fuel. If you are looking for a system which has the possibility of going to a very low enrichment, and you wish to avail yourself of the obvious advantages of gas cooling, then I think the type of advanced Calder Hall system offers a very interesting route in that respect.

I would suggest that in the very long future looking toward the lowest cost of electricity, irrespective of the fuel enrichment used—and obviously here I hope to avoid bias but at least I am one-sided as a witness because I am in love with our system, I would assume that our system would eventually show that our system has the highest potential and can get us there, because of the very high temperatures to which it can ultimately be extrapolated. When I say this I am not thinking merely of using it in terms of graphite fuel elements, but perhaps in the distant future going to other ceramic fuel elements, like homogeneous beryllia-type fuel elements. I would say as a class of reactor that this reactor has an exceedingly high promise and I would think would lead to the lowest central station power costs.

Representative HOSMER. What we essentially have is two concepts on this large-scale gas-cooled powerplant today whereas we were dealing essentially with one at this time last year.

Dr. DEHOFFMANN. That is right.

Representative HOSMER. I just want to ask one more line of questions and that is in relation to graphite work. Has anybody beside you and the people down at Los Alamos been doing graphite work?

Dr. DEHOFFMANN. Thank you, I am very happy you brought that up, Congressman Hosmer. I think the state of technology of the

graphite work has been progressing in the last few years and has led us to feel that this is the time now to go ahead with this kind of project. In this country several of the carbon companies, in Europe several of the carbon companies, and in fact, your chairman, Senator Anderson, was kind enough to point out to me there is one in Germany that is working on it. I think you will find there is increased work on this subject all around the world. As with all good technical ideas, there seems to come a time in the life of the technical idea that everybody in the world is beginning to work on it.

Representative HOSMER. What are these companies working on?

Dr. DEHOFFMANN. They are working to try to produce as impermeable graphite as they can.

Representative HOSMER. That is all, Mr. Chairman.

Chairman ANDERSON. I think that completes the testimony for this morning. We will meet at 2 o'clock this afternoon. Thank you, Dr. deHoffmann, for being here.

Dr. DEHOFFMANN. Thank you very much, Mr. Chairman.

(At 12:20 p.m., a recess was taken until 2 p.m., the same day.)

AFTERNOON SESSION

Chairman ANDERSON. The committee will be in order.

Our first witness this afternoon is Mr. Samuel B. Morris, of the American Public Power Association.

Mr. Morris, you have been a witness many, many times, but in another committee, and I am very happy to have you here this afternoon.

STATEMENT OF SAMUEL B. MORRIS, CHAIRMAN, ATOMIC ENERGY COMMITTEE, AMERICAN PUBLIC POWER ASSOCIATION

Mr. MORRIS. I am very happy to be here, and I appreciate your courtesy in inviting the American Public Power Association to present a statement before you.

I have with me Mr. James L. Grahl, director of the atomic energy service of the American Public Power Association.

My name is Samuel B. Morris. I am appearing here in behalf of the American Public Power Association as chairman of the atomic energy committee of that organization. The American Public Power Association is a nonprofit association representing more than 1,000 local publicly owned electric utility systems in 43 States and Puerto Rico. The headquarters of the organization is 1025 Connecticut Avenue NW., Washington 6, D.C.

My position is consultant to the Department of Water and Power of the City of Los Angeles, Calif., and others. I was formerly general manager and chief engineer of the department of water and power. Before taking the Los Angeles position in 1944, I was dean of engineering at Stanford University. As you know, I was a member of the panel on the Impact of the Peaceful Uses of Atomic Energy (McKinney Panel) which was set up by this committee.

Our association regards the publication of the "Proposed Expanded Civilian Nuclear Power Program" by the Joint Committee on Atomic Energy as a most important forward step and a valuable

contribution toward establishing the objectives and content of an adequate program for nuclear power development, and of the policies under which it should be accomplished.

I would like to take this opportunity to thank the Joint Committee for the opportunity for a representative of this association to participate in the advisory panel which helped in the preparation of the proposed program.

We agree in large part with the recommendations contained in the proposed program. Our views on the proposed program were covered in detail in a memorandum of November 15, 1958, by Mr. Grahl of our staff which was transmitted to the Joint Committee. In this statement, I will mention only briefly the principal modifications to the program which we would suggest.

1. We suggest that the program objectives be stated in more specific terms and that goals for 5 or 6 years hence rather than 10 to 12 years in the future be adopted. These changes, in our opinion, would result in a more effective program.

2. Both the domestic and foreign goals seem too conservative. There is considerable qualified opinion that nuclear power competitive in high fuel cost areas of the United States can be achieved several years earlier than the 1970 target date in the proposed program.

Likewise, the British, Italians, and French expect to achieve nuclear power competitive in high fuel cost areas during the period 1962–65, and the proposed program's target date of 1968 for foreign countries, therefore, does not seem likely to "fortify the position of leadership of the United States in the eyes of the world." As you know, the British expect their 500,000 kilowatt Hinckley Point plant to produce power at a competitive cost, and this is scheduled to go into full operation in 1962.

3. We recommend that whatever program is adopted provide clearly for the development of economically practical plants in the size range of 50,000 kilowatts and below. We submitted a detailed memorandum on this subject to the Atomic Energy Commission in December at the request of Chairman John A. McCone and copies have been supplied to the Joint Committee.

(The forwarding memo and statement referred to follows. See also app. 8, p. 625.)

FEBRUARY 25, 1959.

Memorandum to: The Honorable Chet Holifield.

From: James L. Grahl, Director, Atomic Energy Service, American Public Power Association.

Subject: The capital subsidy proposal as it would affect participation in the atomic power program by local public power systems and rural electric cooperatives.

I am pleased to submit this memorandum in response to your informal request subsequent to testimony by Mr. Samuel B. Morris and myself during the Joint Committee hearings on February 19, 1959. This memorandum will provide the somewhat more detailed explanation which you desired of why, as a general rule, Federal capital subsidies of 50 percent of the total cost of a plant would not provide a workable basis for the sponsorship of developmental nuclear power projects by local publicly owned electric systems or rural electric cooperatives.

As the two types of systems obtain their capital financing in different ways, I will discuss each type in separate sections of the memorandum.

LOCAL PUBLICLY OWNED SYSTEMS

The local publicly owned electric systems in the United States include municipally owned utilities, public utility districts, and State power agencies. Of these types of local public systems, the municipals are by far the most numerous. There are about 2,000 of these in the United States, ranging in size from the department of water and power in Los Angeles, Calif., to very small systems serving small towns. The great majority of municipal systems are relatively small utilities serving the consumers within their city or town limits.

The local publicly owned systems are self-supporting and as a general rule obtain funds for financing the construction of generating plants by the issuance of revenue bonds sold in the private money market. Usually, some capital investment also is financed out of reserves but these are no larger than the minimum required to maintain a sound fiscal position.

The Atomic Energy Commission has suggested a program for nuclear power development under which the Government would offer cash subsidies to utilities of up to 50 percent of the total cost of a nuclear powerplant.

Generally speaking, the local publicly owned systems would not be able to participate in the nuclear power development program on this basis. The reasons for this are as follows:

1. The 50 percent subsidy would still require the utility to make some investment in the reactor system. For example, if a 20,000 kilowatt nuclear plant were to cost $400 per kilowatt, the utility would need to invest $200 per kilowatt, or $4 million. This would mean a utility investment of approximately $100 per kilowatt in the reactor portion of the plant.

Even though the $200-kilowatt cost might be comparable to the cost of a conventional plant of this size, the utility nevertheless would be investing roughly $2 million in a reactor with uncertain performance characteristics, maintenance problems, and lifetime.

The prognostications for the performance, reliability, and lifetimes of nuclear plants are encouraging, but at present these remain uncertain quantities. The nuclear plants are obviously developmental or there would be no apparent justification for proposing such heavy public subsidies.

2. As a general rule, the local public systems are in no position to invest what for them are sizable sums in experimental plants. They do not have reserves available for relatively large research and development expenditures. Their revenue bonds must be for the construction of dependable capacity which will produce earnings sufficient to service and pay off the bonds.

3. In many cases, there are legal limits on the borrowing a public system can engage in, to the extent that systems often have a hard time financing the additional capacity required to keep up with growing loads, let alone issuing bonds to finance a developmental plant of uncertain reliability.

4. In some States there are legal requirements that public agencies make only economically prudent investments or that otherwise prevent investments in developmental facilities.

5. A capital subsidy would not meet the possible problem of abnormally high fuel, operating, and maintenance costs of a developmental reactor.

6. The municipal systems generally serve a relatively restricted area and any additional costs due to the financing and operation of a power reactor would be spread over a relatively small group of consumers. Putting this another way, a 20,000-kilowatt plant on a 100,000-kilowatt system is not a negligible matter, and if the plant proves unsatisfactory the economic effect on the system and on its consumer-owners would not be negligible if the utility had invested in it significantly.

7. Apart from legal limitations, the local publicly owned systems have not believed that they can justify burdening their consumers with the financial risks and possible costs of investments in developmental reactors.

This belief stems from the basic characteristic of local publicly owned electric utilities, that of being nonprofit public agencies. Their earnings above costs, depreciation, and debt service go back to the local community as payments in lieu of taxes and back into the system as investments in utility improvements. If earnings exceed the needs, the general pattern is to reduce rates.

That a 50 percent capital subsidy is not workable as a general policy for participation by the local publicly owned electric systems in the nuclear power development program is best illustrated by consideration of the projects proposed to date by local public systems.

The 12,500-kilowatt plant proposed by the city of Piqua, Ohio, under the terms of the second round would not even have been proposed if the 50 percent subsidy policy had been in effect. The city is supplying the site and existing turbine-generator capacity for this plant, expenditures which fall far short of 50 percent of total plant cost. If Piqua were having to purchase a turbine-generator for the nuclear plant, its investment would approximate one-fourth to one-third of total plant cost.

The same statement applies to the proposal made by the city of Holyoke; it would not have been made at all under a 50-percent capital grant policy.

Consumers Public Power District of Nebraska, which made its proposal under the first round, is very much larger than the systems of Piqua and Holyoke. Under its contract with the Atomic Energy Commission, Consumers will finance the conventional portions of the plant and contribute $5.2 million toward the cost of the reactor system, estimated to cost $27 million. Total Consumers investment will be $16.8 million, about 38 percent of total plant cost. Consumers is the largest public power agency to have proposed a nuclear project and its investment is larger than that proposed by any other local public system. Nevertheless, it did not propose to invest 50 percent of total costs. To increase its investment to this level would have required an additional $5 to $6 million beyond Consumer's ability to invest. The general manager of Consumers told the Joint Committee in June 1957 that, as regards their financing of plant construction and operation, "we can't afford to have any substantial increase in the overall cost [of power]."

As you know, the terms of the "second round" as modified by the Congress, were carefully drawn to protect the utilities against any significant increase in the total cost of power by providing for Federal financing and ownership of the reactor and partial Federal financing of operating costs. This still appears to be the only basis on which the local publicly owned systems generally can participate in the nuclear development program.

RURAL ELECTRIC COOPERATIVES

The following comments on the position of the rural electric cooperatives are included at your request. I believe them to be correct, but I would suggest that for confirmation and perhaps further details you may wish to get in touch with the National Rural Electric Cooperative Association.

The situation of the rural electric cooperatives is very similar. There are about 1,000 of these systems and, as you know, they obtain their capital financing through loans from the Rural Electrification Administration.

The REA states that under the law it cannot make loans to finance any portion of the reactor system of a nuclear powerplant at the present stage of the technology. In testimony before a subcommittee of the House Committee on Appropriations in February 1958 (pt. 3, p. 1876), Mr. Kenneth Scott (Director of Agricultural Credit, Department of Agriculture) testified that "Since atomic energy facilities in connection with power production are considered at the present time to be experimental in nature, REA has no authority to finance the nuclear portion of a borrower's generating facilities * * *."

As a consequence, the REA approved a loan to the Rural Cooperative Power Association, Elk River, Minn., for the conventional turbine-generator but no funds for the reactor system. The turbine-generator investment will be $1,750,000 and the reactor investment (being made wholly by AEC) $8.2 million. The Elk River proposal could not have been made if the 50-percent capital grant policy had been in effect.

The same statement applies with equal force to the proposals of the Chugach (Alaska) rural electric cooperative and the Wolverine (Mich.) cooperative. It also applies to the second proposal presently being considered by Wolverine.

The REA position on this question has been very clear. There seems no room for doubt that no rural electric cooperative could participate in the nuclear power development program except upon terms similar to those provided under the second round, with AEC financing for the reactor system and for reactor fuel and operating costs in excess of the utility's conventional steam costs.

This review of the financial situations of the consumer-owned systems inevitably raises the question of why they should desire or be enabled to participate in the nuclear power program. There are good and sufficient answers to this question, and they are set forth in considerable detail in the attached copy of a memorandum prepared at the request of the Chairman of the Atomic Energy Commission in December 1958.

AMERICAN PUBLIC POWER ASSOCIATION,
Washington, D.C., December 17, 1958.

MEMORANDUM—SUBJECT, PARTICIPATION BY CONSUMER-OWNED ELECTRIC UTILITIES IN POWER REACTOR DEMONSTRATION PROGRAM

This memorandum has been prepared at the suggestion of the Chairman of the Atomic Energy Commission, Mr. John A. McCone, in order to summarize a discussion with Mr. McCone on December 12, 1958, by representatives of the American Public Power Association and the National Rural Electric Cooperative Association.

The local publicly owned electric utilities and the rural electric cooperatives desire to continue to participate in the Atomic Energy Commission's power reactor demonstration program. Under existing AEC policies, such participation is not possible.

Continued participation by these consumer-owned systems is important for such reasons as the following:

1. To assure the development of economic nuclear powerplants in the small and moderate size ranges—say, about 5,000 to 50,000 kilowatts of electrical capacity.

2. To assure that such plants are developed and designed with the requirements of the smaller utility systems specifically in mind.

3. To provide an adequate opportunity for engineering and management personnel of consumer-owned systems to become conversant with nuclear power technology, so that this segment of the power industry will have available experienced leadership for the future transition to the use of nuclear power on an economic basis and, equally important, have firsthand knowledge of the actual costs, health and safety aspects and potentials for improvement of nuclear power facilities.

4. To make available to the national atomic power development program the experience of the local publicly owned systems and the rural electric cooperatives in power production.

Comments on these points are provided in the paragraphs below.

THE DOMESTIC NEED FOR SMALL NUCLEAR POWERPLANTS

There are approximately 2,000 municipally owned electric systems and 1,000 rural electric cooperatives in the United States. The need for economical small nuclear powerplants will arise largely from this group of 3,000 systems. In a 1955 study, it was estimated that this segment of the industry would represent a potential domestic market by 1973 for at least 1,160 units of average electrical capacity of 20,000 kilowatts, exclusive of replacements for old conventional units.

In addition, the study found that there were in excess of 900 industrial plants and privately owned utilities having a potential need for production units of 75,000 kilowatts or less.[1]

Thus, there is not only a sizable market but the number of units in this potential market is many times the number of large units for which a future market exists. There is therefore a much greater opportunity for economy through the repetitive manufacture of many small units.

THE NEEDS OF UNDERDEVELOPED COUNTRIES

In addition to these potential domestic requirements, it appears that the United States needs to develop economic small nuclear powerplants to help meet its express international commitments. In many of the underdeveloped areas of the world, there is little or no opportunity for economic use of a large reactor.

The substantial need for nuclear power in the underdeveloped countries was described at the 1958 Geneva conference on the peaceful uses of atomic energy by Dr. Homi J. Bhabha of India in his evening lecture. Dr. Bhabha stated that:

"* * * The vast region of South-Asia and the Far East excluding China, with a population of some 775 million, is the most poorly endowed per capita with conventional energy resources, and any substantial rise in the standard of living

[1] "Need in the United States for Small Power Reactors," by Samuel B. Morris. Paper P/849 presented at the International Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland, August 1955. Vol. 1 of the proceedings, p. 432 ff.

of the region as a whole will only be possible on the basis of very large imports of fuel or on the basis of atomic energy. While not as badly placed as SAFE, Latin America is more poorly endowed per capita in natural energy resources than the three other underdeveloped regions, and one may expect atomic power to appear there on a considerable scale earlier than in any of the other underdeveloped regions, except SAFE * * *"

Studies of the prospects for atomic power in India and Brazil made by the National Planning Association in recent years concluded that small and moderate-size nuclear powerplants—in the 5,000 to 50,000 kilowatts range—would be highly useful for interior development of both of these countries.

The United States has made explicit promises to assist the underdeveloped areas of the world in the utilization of atomic power. Thus, quite apart from domestic needs, there exist strong reasons for establishing a coherent U.S. program for the early development of economic small nuclear powerplants for civilian use.

PRESENT STATUS OF SMALL POWER REACTOR DEVELOPMENT

Because of the economies of size in nuclear power units, the emphasis of the U.S. atomic power program has been on the development of large power reactors. With the possible exception of the plant under construction on the system of the Rural Cooperative Power Association of Elk River, Minn., there is at present no project underway or planned which has as its primary purpose the development of an economic small power reactor.

The numerous small civilian power reactors which have been built or proposed have been reactor experiments or small experimental prototypes with the primary purpose of proving out technology for large reactors. While these reactors furnish a great deal of technical data of importance to reactors of all sizes, they provide only limited reliable information on the probable economics of small plants. Their unit costs, for example, are considerably increased by their experimental aspects, looking toward the design of very large units. Furthermore, they do not exploit the possibilities for cost reductions in small plants designed explicitly for commercial use, through simplification, the use of less exotic materials where possible, etc.

This is also true of the small reactors built or under design for military applications. These are designed for special uses and to meet military requirements. The cost of power is apparently not a primary consideration and these plants also provide little conclusive information about the possibilities for developing and designing economic small civilian central station plants.

In short, there is at present no program specifically directed toward the development of a practical small civilian plant.

COSTS OF SMALL NUCLEAR PLANTS

It is recognized that the unit cost of small nuclear plants, at least initially, will be higher than that of a large plant of the same type. While there is a considerable body of opinion among reactor experts that the development of an economic small plant—in the 5,000 to 50,000 kilowatt size range—may be so difficult as to be very far in the future, there also are experienced reactor engineers who are optimistic about the chances for success if a fresh approach is adopted with the objective of developing commercial plants specifically for small and medium-size systems.

The fact is that the effort has yet to be made. It is our belief that a determined effort to design and build a series of minimum cost small nuclear plants, with each plant improving upon the design of the former ones, would demonstrate that the achievement of competitive nuclear power using relatively small units is a definite possibility.

Furthermore, there are certain nontechnical considerations which tend to offset factors which may cause unit costs of small plants to be relatively high. Thus, the local publicly owned systems and rural electric cooperatives can assume fixed charges of about 8 percent to 9 percent per year, as compared with fixed charges of 13 percent to 15 percent typical of the privately owned utilities. The lower fixed charges of the nonprofit systems thus would permit unit capital costs 50 percent to 90 percent higher than those for large units on privately owned systems, and still result in the same cost per kilowatt-hour for fixed charges.

Another offsetting factor is the fact that the small nuclear plant must be competitive, not with the modern large conventional thermal plant, with its production costs of 4 to 8 mills, but with small conventional plants which produce power at from 8 to 15 mills, depending upon fuel costs and other local factors. A small nuclear plant would enter the competitive area in a meaningful number of locations if it could produce power at 10 to 12 mills per kilowatt-hour and of course would find a still larger market when costs were reduced to 8 to 10 mills.

Additionally, the much larger number of units in the potential small plant market would offer the opportunity for economies through repetitive manufacture of many units which would help offset the higher costs otherwise associated with a small plant.

REQUIREMENTS OF THE SMALLER UTILITY SYSTEMS

There are some differences in requirements between the smaller systems and the very large utilities which use large generating units. It would require a careful study to disclose the more significant differences and how they would affect reactor design. One obvious difference of a nontechnical nature may illustrate the point. The privately owned utilities are in general larger than the consumer-owned systems and their requirements have tended to dominate U.S. power reactor design assumptions. The privately owned companies have relatively high fixed charges, so their emphasis and that of the AEC program is on the development of reactors with relatively low capital costs and high fuel costs, compared to some reactor types. (This tendency is of course also encouraged by other factors, such as a plentiful supply of enriched uranium fuel for which no private investment is required.)

On the other hand, the smaller utilities are mostly consumer owned and have relatively low fixed charges. It is quite possible that the types of reactors under development in the United States are particularly ill suited to the economics of these systems. A small plant with relatively high capital costs and very low fuel costs might well be the answer for these systems. Yet no serious investigation of this has been made, to our knowledge, nor is an effort going forward to develop a small plant with these characteristics.

PARTICIPATION BY PERSONNEL OF CONSUMER-OWNED SYSTEMS

The principal interest in the utility industry in the development of relatively small economic nuclear powerplants is in the consumer-owned segment of the industry. If the local publicly owned systems and rural electric cooperative are foreclosed from participation in the atomic power program, the development of such plants seems unlikely. The primary interest of the privately owned segment of the industry is in large units and the tendency of the AEC also has been to concentrate attention on economic large units, except for special military applications.

If the development of types of practical nuclear plants in the 5,000- to 50,000-kilowatt range is important in terms of domestic requirements and to meet our international commitments, and we believe that it is, then participation by the consumer-owned systems appears necessary if such a development program is to go forward. To date, the necessary interest has not been evident in other quarters.

Furthermore, the whole U.S. atomic power development program rests on the assumption that at some time in the future nuclear power will play an important role in the domestic power industry. We certainly agree with this assumption and accordingly believe it most important that within the consumer-owned segment of the industry there be developed a group of engineering and management personnel with firsthand knowledge and experience in nuclear power technology.

To a degree, this need be and is being met by study and academic training, but these are not adequate substitutes for actual experience. It will not be satisfactory, either, for this segment of the power industry to leave the operation of developmental plants largely in the hands of large aggregations of privately owned utilities. As long as there is going to be a demonstration program with joint Federal and utility financing and responsibility, it is necessary for a reasonable number of consumer-owned systems to participate actively. For obvious reasons, it would not be satisfactory for these systems to have to depend heavily upon cost data and technical information derived from projects not particularly suited to nonprofit system requirements and developed through undertakings dominated by their competitors.

Finally, the largest group with experience in small utility system operation is found in the local publicly owned systems and rural electric cooperatives. Qualified people from this group can make definite contributions to the development of small nuclear powerplants if given the opportunity.

PROGRAM SUGGESTIONS

Without attempting to go into detail, we would suggest that a small plant development program provide (1) for an engineering study to determine the best possibilities for developing economic small plants in terms of the financial aspects and operating requirements of "typical" municipal and rural cooperative systems, (2) the development and construction of several small plants designed to achieve minimum costs, (3) the operation of these plants to obtain data and experience, and (4) the construction of several more plants to incorporate further design simplifications, cost reductions, and other improvements.

It is recognized that the Commission's "second round" fell short, in some respects, of expectations. However, its major shortcomings are correctable. Procedural changes could improve greatly the results of a newly planned small power reactor program. Thus, if the Commission were to specify in its invitation the types and sizes of plants for which proposals were desired and some general criteria as to plant site, a large number of the difficulties encountered in the second round would be prevented.

In initiating such a small-plant development program, the Commission might also consider basing it heavily upon known technology, rather than requesting proposals for exotic designs as in the second round, and invite proposals for plants which incorporate improvements on reactor types on which considerable development has already been done.

PRESENT LACK OF OPPORTUNITY TO PARTICIPATE

Under the terms of the Commission's third invitation for proposals, the local publicly owned systems and rural electric cooperatives are not now able to participate in the atomic power development program. For the following reasons, these terms are suited only to participation by the privately owned utilities:

1. The local publicly owned systems and rural electric cooperatives are nonprofit operations, and most are much smaller than the average privately owned utility. They do not have the large financial resources needed to finance the entire capital cost of an atomic powerplant. In many cases, there also are legal limitations on investments in uneconomic projects. The rural electric cooperatives cannot borrow any funds from the REA to finance a nuclear power reactor, but are limited to financing only the site and conventional turbine-generator portion of an atomic power facility.

2. The difficulties, legal and otherwise, of municipally owned systems and rural electric cooperatives combining to finance jointly the construction and operation of a nuclear power facility make this a practical impossibility.

3. On the other hand, the private power companies are able to shift all or most of the abnormally high costs of an atomic power project to their customers. With few exceptions, State regulatory commissions are allowing the private utilities to charge the full costs of these projects into their operating and capital expense accounts. These costs thus eventually will be covered by higher rates.

4. The private power companies are able to form large combinations to finance atomic power projects and spread the costs over a very large number of consumers and a large financial base. With one exception, every private utility project proposed under the demonstration program is being sponsored by an aggregation of private power companies.

5. Even with their much larger financial resources, there is increasing evidence that the privately owned utilities are having difficulties in financing projects. It is therefore not surprising that the nonprofit systems cannot finance developmental reactors.

PREVIOUS INVITATIONS ALLOWED PARTICIPATION

In its first two invitations, the Commission recognized the legal and financial situation of the rural electric cooperatives and the local publicly owned utilities and provided for Federal financing and ownership of power reactors. The proposal of the Consumers Public Power District of Nebraska thus was accepted

under the first invitation and the proposals of the Rural Cooperative Power Association (Elk River, Minn.) and of the city of Piqua, Ohio, were accepted under the second invitation. In all cases, the Federal Government agreed to finance all or most of the cost of the reactor and retain title to it. In the latter two cases, AEC will sell the steam produced at the price of comparable conventionally produced steam.

The provisions gave the consumer-owned systems an opportunity to participate in the U.S. atomic power development program and contribute to the development of reactor types of interest on terms which did not require unacceptable financial burdens. At the same time, they provided for no more Federal financing than necessary to cover the above-normal costs and risks involved in these experimental projects. The accepted projects represent valuable elements of the technical developmnt program.

PREVIOUS POLICY SHOULD BE REINSTATED

AEC's third invitation thus represents an important and, in our opinion, a most unfortunate departure from previous Federal policy. The effect of the terms of the third invitation has been to deny the opportunity to participate to all except the privately owned utilities.

We urge that the earlier policies of the Commission and the Congress which did recognize and accommodate the differences between the consumer-owned utility systems and the private power companies be reinstituted, as a matter of equitable treatment by the Government of the types of utility systems which make up the power industry in this country. Specifically, we request the establishment of a new small power reactor program, with substantially the same financing arrangements as were established for the second round, including Federal capital financing of the reactor system.

In this connection, it is of interest that during the Senate debate on July 15 on the 1959 AEC authorizing bill, Senator Clinton Anderson stated—in response to a question by Senator Hubert Humphrey—that—

"I think it [sec. 109 of the bill] practically excludes them [rural electric cooperatives and local publicly owned systems], because the Government must finance them completely. Therefore, we shall require another program, as we did in round two, permitting the Government to pay the entire cost, as at Elk River, and as has been suggested at other spots."

If the rural cooperative and municipal systems continue to be excluded from further participation in the demonstration program, the development of commercially practical plants in the 5,000 to 50,000 kilowatt size range is apt to be neglected, the role of the consumer-owned utilities in the power industry will be diminished, and their long-run competitive position—already difficult enough—may be endangered.

RESOLUTIONS ON ATOMIC ENERGY ISSUES ADOPTED BY THE MEMBERSHIP OF THE AMERICAN PUBLIC POWER ASSOCIATION AT ITS NATIONAL CONVENTION, MAY 8, 1958, NEW ORLEANS, LA.

PATENT LICENSING IN ATOMIC ENERGY FIELD

Whereas the provisions in the Atomic Energy Act of 1954, which authorize the Government to compel the cross-licensing of privately owned patents in the atomic energy field when this is found to be in the public interest, with reasonable compensation to the patent owner, will expire for patents applied for after September 1, 1959; and

Whereas the technology of atomic power is still in its early stages and obviously will continue to be in a state of active and rapid development for many years; and

Whereas it appears probable that the atomic power equipment manufacturing industry will become a major and basic industry in this country; and

Whereas the bulk of the research and technological development has been carried on and developed to date at public expense and it appears that this will continue to be true for some years; and

Whereas the provisions for compulsory cross-licensing of atomic energy patents apply also to the new and potentially extremely important field of controlled fusion power, which is at the beginning of what is predicted will be a 20-year period of research, scientific, and technological development; and

Whereas in the absence of a reserve power by the Government to compel cross-licensing with reasonable compensation, there will be opportunities after September 1, 1959, for the development of unregulated private patent monopolies which could seriously and adversely affect the development of low-cost atomic power from the fission or fusion reactions: Now, therefore, be it

Resolved, That the American Public Power Association urges the Congress to amend the Atomic Energy Act of 1954, and specifically section 153 h. of that act, to extend the Government's authority to compel the cross-licensing of privately owned patents in the atomic energy field for an indefinite period, or at least to September 1969, and to simplify and strengthen the patent cross-licensing provisions of that act.

SMALL ATOMIC POWERPLANTS

Whereas the American Public Power Association in three previous annual conventions adopted resolutions in the interests of the approximately 2,000 local publicly owned and 1,000 rural cooperative electric systems in the United States, most of which are relatively small, urging upon the Atomic Energy Commission the importance of developing low-cost atomic powerplants to produce electric power economically in the range of 5,000 to 50,000 kilowatts; and

Whereas the Atomic Energy Commission recently approved in principle contract arrangements with the municipal electric system of Piqua, Ohio, a member of this association, and with the Rural Electric Cooperative Association of Elk River, Minn., to build small atomic powerplants with Government aid; and

Whereas there is no significant program other than these proposed projects which provides for the development of small commercial nuclear powerplants; and

Whereas the expeditious construction and operation of these demonstration units is a most important factor in the development of commercially practicable small atomic power units for domestic use and especially for use in the underdeveloped nations of the free world: Now, therefore, be it

Resolved, That the association commends AEC's recent favorable action on the Piqua and Elk River projects, urges that these projects be undertaken expeditiously, and recommends that additional developmental projects be initiated to strengthen the program of small nuclear powerplant development.

NUCLEAR POWER DEVELOPMENT PROGRAM

Whereas our fossil fuel reserves are exhaustible and nuclear energy must be developed expeditiously to provide the American people with an ever-increasing supply of low-cost electric power; and

Whereas international considerations also require a vigorous and effective atomic power development program; and

Whereas the country's foremost power reactor experts last fall unanimously agreed that the U.S. atomic power program lacks clear objectives and policies; and

Whereas these same experts have pointed out that the present demonstration program for full-scale power reactor construction is inadequate to meet what should be the U.S. objectives in atomic power development; and

Whereas the conclusions of these experts and of other nonpartisan, well-informed groups tend to confirm the position taken for several years by this association that substantial additional Federal full-scale plants should be undertaken promptly in order to strengthen and accelerate the U.S. atomic power program; and

Whereas such additional Federal projects are critically needed to advance the development of economically practical atomic powerplants, in both the small and large size ranges; and

Whereas reports recently transmitted to the Joint Committee on Atomic Energy by the Atomic Energy Commission and other related information show the feasibility of building a 40,000- to 60,000-kilowatt atomic powerplant using a gas-cooled reactor and a 300,000- to 700,000-kilowatt dual-purpose plant: Now, therefore, be it

Resolved, That the American Public Power Association hereby urges that the U.S. Government assert more positive leadership by adopting a clear policy and program, with definite objectives in both the domestic and international fields; and be it further

Resolved, That the association urges the U.S. Government to undertake in the public interest the construction and operation of atomic powerplants of

representative sizes and types, in addition to projects proposed under the present demonstration program, including as a minimum the 40,000- to 60,000-kilowatt gas-cooled plant and 300,000- to 700,000-kilowatt dual-purpose plant on which the AEC has completed preliminary studies and one or more plants in the 10,000- to 40,000-kilowatt size range.

Mr. MORRIS. I am most gratified to note that in his testimony before this committee this week, Mr. McCone stated that the Commission has initiated an intensive study to determine the reactor concepts of greatest promise for plants in the 5-to-40-megawatt range, and proposes to start construction of a 20-megawatt plant during this fiscal year.

We heartily commend the Commission for initiating a systematic small plant development program. It fills a longstanding gap with which this association has been particularly concerned due to the large number of local publicly owned utilities of small and medium size for which such plants would be suitable.

The need in the United States for plants in this size range is indicated in a paper which I submitted to the first United Nations conference on the peaceful uses of atomic energy in 1955. I estimated that by 1973 there would be a potential domestic market for at least 1,160 units of an average electrical capacity of 20,000 kilowatts each, exclusive of replacements for old conventional units.

There also is strong interest in plants of this size abroad. The International Atomic Energy Agency has initiated studies of the possibilities for utilizing nuclear power in underdeveloped countries and of the technical suitability of reactors with capacities up to 50 megawatts, and plans to hold an international conference on small- and medium-size power reactors in 1960.

The newly announced Commission program for small plant development will thus meet needs of the underdeveloped nations as well as domestic requirements.

4. As in past years, we urge the adoption of a substantial Federal nuclear power plant construction program. This should include experimental prototypes as recommended by the proposed program and, in addition, some second-generation plants. If the United States wants to achieve some specific goals by definite dates and wishes to lay out a program to do so, this can be done with much more certainty with a Federal program of plant construction than with a program which waits for proposals from private groups and depends upon the possibility that such proposals if made will happen to fit in with the overall program and be carried forward so as to meet the program goals and time schedules.

A program of AEC atomic power projects would provide a firm base for the U.S. development effort but it is not our view that the adoption of a Federal program should preclude additional projects which might be proposed by utility systems under the demonstration program.

The American Public Power Association, therefore, supports legislation along the lines of S. 683, the bill introduced last month by Senator Albert Gore. As we have stated before, we do not regard this as public power legislation.

In respect to the AEC demonstration program, I should like to renew our previous recommendations that the terms under which projects can be proposed be amended to enable the local publicly owned utilities and rural electric cooperatives to participate. Their

nonprofit character and other circumstances require at this stage in the technology that AEC provide financing under terms similar to those established for the second round.

Representative HOLIFIELD. You know, of course, that there is nothing asked for in the program for that type. In the authorization bill which was sent up to us on the 17th of this month, that is.

Mr. MORRIS. Yes, that is my understanding.

Representative HOLIFIELD. You understand that there is nothing asked for, but there is in the language of the bill an exclusion of anything along that line. If you will wait just a minute, I will read it to you [reading]:

SEC. 113. Section 109 of Public Law 85-590 is amended by striking out the figure of $155,113,000 and $175,113,000, and inserting in lieu thereof the figure of $135,000,000 and $155,000,000: *Provided*, that after date of enactment of this Act the Commission shall not consider any new project proposals under arrangements of the first, second, or third round of the power reactor demonstration program.

Mr. MORRIS. Yes, I recognize that. I feel and the American Public Power Association feels that there is greater opportunity of the Federal Government moving ahead with that type of a contract and building in accordance with the advanced technical requirements which they desire, rather than being limited to what may be negotiated into a provision of a private undertaking.

Representative HOLIFIELD. I did not get the last statement.

Mr. MORRIS. Rather than the negotiations which might lead into a cooperative agreement with a utility to build a specific reactor, we believe the Government would have wider latitude in this type of arrangement than they have in the contract type, even though the Federal Government may donate a portion of the cost.

Representative HOLIFIELD. Do I understand you to recommend that the Government should go ahead in this area of research and development on its own rather than participate in any type of operation such as the second round?

Mr. MORRIS. Yes, that is correct.

Representative HOLIFIELD. You do? Do you understand my question?

Mr. MORRIS. As I understand your question, it was whether we felt they should have this privilege under the second round in addition to the Government being able to go ahead by itself under the provisions of the Gore bill. Is that correct?

Chairman ANDERSON. What you have just got through saying, Mr. Morris, was that you felt that it was undesirable for public power to have anything to do with the program. You are speaking for the American Public Power Association. Will you try to reconcile those two things? You have said that you don't believe in the second round being continued. That is the only way that these utilities can get into it. Who are you speaking for?

Mr. MORRIS. I endorse the second round, and if I made a misstatement it is my error.

Chairman ANDERSON. I know you well enough to know, Mr. Morris, that you did not understand Mr. Holifield's question. He pointed out that under the provisions of this authorization bill that is sent up here, it is specifically provided that the Atomic Energy Commission can-

not go ahead any further under the second round, meaning that REA projects like Elk River, public project like Piqua, and so forth, are out in the future.

Mr. MORRIS. Yes.

Chairman ANDERSON. Did I understand you to say that you endorse that point of view?

Mr. MORRIS. No.

Chairman ANDERSON. I thought not.

Mr. MORRIS. I thought that should be amended.

Representative HOLIFIELD. That is why you probably saw a confused look on my face because I felt you didn't understand my question. It is possible I did not propound my question clearly.

Representative HOSMER. Do you see a possibility of the public power group being assisted by the capital contribution feature that Mr. McCone mentioned in his testimony?

Mr. MORRIS. Yes.

Representative HOSMER. In other words, this capital contribution more or less takes the place of some assistance under the demonstration program.

Mr. MORRIS. I think in part it does. But I don't think it gives the Government as much latitude in proceeding promptly with a type of reactor in which it might desire to explore certain specific fields as much as it would if it had to negotiate a favorable contract with some utility, public or private, to carry out a type of development which is also acceptable to a utility.

Representative HOSMER. It is, however, somewhat of a Government assistance for attaining the same ends.

Mr. MORRIS. It is Government assistance without as much control. That is my expression.

Representative HOLIFIELD. Let us explore the factor of participation on the basis of this capital grant on the part of REA cooperatives. As I understand, the REA cooperatives do not have substantial reserves on hand for capital plant investment, is that right?

Mr. MORRIS. I believe that is correct.

Representative HOLIFIELD. Under the law in order to have a capital plant investment they must obtain a loan from the Government for that purpose, is that right?

Mr. MORRIS. Yes, I think that is generally true, although I do not speak for that group.

Representative HOLIFIELD. I think it is well known that is the law. In the case of an REA that wishes to go into this type of operation, would the subsequent financial risk which would be involved in a high-priced reactor—in the high-priced kilowatt from a reactor that would also be high priced in terms of capital investment—even though part of that capital investment was borne by the Government, could they qualify under that type of plant for a loan under the REA act?

Mr. MORRIS. I think if there was a substantial hazard involved that they probably could not.

Representative HOLIFIELD. Of course, there is a substantial hazard because notwithstanding the fact that under the generally accepted formula which has been discussed—it has not been written into law yet—the Government steps in and takes up 85 or 90 percent differential in the capital plant investment. Although the Government

does make available heavy water moderator or fuel, you might say on a grant basis or a free basis for a certain period of time, notwithstanding that fact the utility has to assume the operational expense of the reactor. I may say operational and maintenance expense of the reactor after it is finished. I think it is generally recognized by all scientists and engineers that this is not gong to be a competitive operation from the standpoint of competition with a conventional fuel plant. So there is a penalty that will be assessed against the utility, whether it be private or public, over the operational area, as well as a penalty on the capital plant investment cost, to that extent to which the Government does not absorb the differential. Do you understand those two points?

Mr. MORRIS. Yes, I do.

Representative HOLIFIELD. Having brought those two points out, do you think that an REA co-op could go to the Government and borrow money under the handicap of those two criteria which does not comply with the present criteria which they have to abide by?

Mr. MORRIS. As nearly as I understand it, they could not safely do so or perhaps legally do so. But I do not represent them and I am not adequately familiar with their legal restrictions.

Representative HOLIFIELD. Mr. Grahl, you are familiar with the criteria by which REA co-ops borrow money. You know what the standards are that they have to comply with. What is your opinion?

Mr. GRAHL. The current policy of REA with respect to nuclear powerplants is that they will loan only that amount of money required to finance the conventional turbine and generator and no more.

Chairman ANDERSON. May I just pause there and say, what would happen under the formula introduced by Mr. McCone the other day to the Elk River plant, for example? He said 50 percent of the total plant cost to the bus bar—I am sure that is what he said, because Senator Gore and I discussed it afterward. In the Elk River plant, Elk River was to provide the site and supporting facilities to cost $700,000. They were going to provide the electrical generating facilities to cost $1,800,000. The rest ran about $10 million. So the total cost was about $13 million. Under Mr. McCone's formula, REA and Elk River would have to put up $6.5 million. You recognize that they could not do that under the criteria you outlined for REA.

Mr. GRAHL. That is right. They could only put up the $1,750,000 for the turbine generator plus the site cost.

Chairman ANDERSON. So REA and Elk River would be out. The same thing applies to Piqua, does it not?

Mr. GRAHL. Yes, sir.

Chairman ANDERSON. The same thing applies to Consumers Public Power District of Nebraska?

Mr. GRAHL. That is right.

Chairman ANDERSON. $50 million out there.

Mr. GRAHL. Yes, sir. They are contributing $5 million to the cost of the reactor, and that plus the cost of the turbine generator does not approach 50 percent of the cost of the nuclear plant.

Chairman ANDERSON. Exactly. So the effect of the formula is to bar any public power whatsoever except maybe in the case of the city of Los Angeles. Mr. Morris knows more about that than I do. It certainly would bar every project we now have, would it not?

Mr. GRAHL. That is right, sir.

Representative HOSMER. May I add, however, that the purpose of the REA program is to provide power at low cost to consumers, and not to engage in research and development of nuclear plants.

Mr. GRAHL. That is the reason why they will not loan funds to help finance the developmental nuclear reactor. Their position is that the law prevents them from doing this.

Representative HOSMER. In other words, it is another Government agency, the Atomic Energy Commission, that is supposed to do this developmental work.

Mr. GRAHL. Yes.

Representative HOSMER. The REA's are supposed to provide kilowatts at low cost to their customers.

Mr. GRAHL. Yes, that is essentially correct, although I believe REA simply stood on the letter of the law.

Representative HOLIFIELD. I think in order that the picture might be complete, the rural cooperative program was entered into by the rural co-ops at the invitation of the Commission. In other words, Consumers of Nebraska, Piqua, Elk River, and all of them responded to an invitation of the Commission.

Mr. GRAHL. Yes, sir.

Representative HOLIFIELD. It was not the joint committee's program. Let the record always be clear that it was not the committee that evolved this program.

Mr. GRAHL. That is correct.

Representative HOLIFIELD. As a matter of fact, the gentleman knows that I have consistently said that the REA's have no business in this program. Is that not true?

Mr. GRAHL. We have had quite a few discussions of that kind.

Representative HOLIFIELD. I am at variance with the gentleman on this opinion. Nevertheless, I want the facts to show that the reason that the co-ops are in on this program is because they were invited by the Commission to come in.

Mr. GRAHL. That is correct, by invitation of September 1955.

Representative HOLIFIELD. That is right.

Mr. MORRIS. Shall I continue?

Chairman ANDERSON. Yes, Mr. Morris.

Mr. MORRIS. The reasons why the local consumer owned utilities desire additional opportunity to participate under the demonstration program, and why terms similar to those of the second round are necessary, are set forth in the previously mentioned memorandum to Mr. McCone, which is attached to this statement.

The city of Burlington, Vt., has submitted just last month a detailed proposal to AEC for development and construction of a nuclear plant of about 50,000 kilowatts of very promising design, based upon months of preparatory study by the municipal utility's consulting engineers and the Westinghouse Electric Corp. The department of water and power of the city of Los Angeles also is actively considering the preparation of a proposal to AEC for a nuclear plant of about 30,000 kilowatts, to serve as a prototype for a large unit in the future. These two cases illustrate the continuing interest by local publicly owned electric systems in further participation in the nuclear power development program.

The foregoing remarks represent the general views of our association and apply also to the report of AEC's ad hoc committee on reactor programs and policy.

In conclusion, I would like to say that we surely hope arrangements will be worked out for proceeding with the 75,000 kilowatt atomic power project of Consumers Public Power District of Nebraska, which are mutually satisfactory to the Government and the district. This project was first proposed to AEC in 1955.

We are gratified that the Atomic Energy Commission has decided to go ahead with the atomic powerplant proposed 3 years ago by the city of Piqua, Ohio. This appears to be very worthwhile from a technical standpoint and of great interest to small and medium-size utilities. This will be the only project under construction on a local public power system.

We wish to endorse the project proposed by the Puerto Rico Water Resources Authority and urge that it be approved for development and construction, assuming favorable findings for the studies presently being made. This project would be a developmental plant using nuclear superheating. If successful, it would be an important advance in developing nuclear reactors capable of being coupled to modern steam turbines.

Finally, the American Public Power Association strongly supports the plan to build a large reactor at Hanford designed so that it can be converted to dual purpose operation. The published report by the General Electric Co. indicated that the cost to the Government for plutonium would be cheaper from a 700 megawatt dual purpose plant than from a single purpose reactor. It therefore seems eminently desirable for the Government to make constructive use of the reactor heat instead of wasting it. A large power-producing reactor such as this also would be valuable in fuel element development and testing and as a training center for the utilities, industries and educational institutions of the Northwest.

Attached to my statement is a copy of the memorandum on small power reactors which I mentioned earlier, and a copy of the resolutions on the atomic power development adopted by the membership of the American Public Power Association at its national meeting last May. I respectfully request that these be included in the record.

Thank you very much for this opportunity to present our views on the U.S. nuclear power program.

Representative HOLIFIELD. You recognize that the Commission has not included in its program the Puerto Rico project?

Mr. MORRIS. Yes.

Representative HOLIFIELD. They brought this program before us some 2 years ago, and the committee insisted that there be some specifics given to us as to what type of reactor, and that the reactor be not just a propaganda machine, but be a substantial advancement of the art. This was agreed to and there was an authorization made and the design study was finished on it. Now you recognize that has been excluded from the program. In their authorization bill they have no funds requested for it.

Mr. MORRIS. I recognize no funds are requested for it. I did not know that there was not still opportunity of continuance on the study.

Chairman ANDERSON. It is not in the authorization bill.

Mr. MORRIS. It is not in the authorization.

Chairman ANDERSON. In other words, you mentioned three things. You mentioned Hallam, Nebr., and I read from Mr. McCone's testimony on page 28:

that is being delayed until fiscal year 1960 in order to take full advantage of the technological and economic improvements which can be built into a sodium-cooled reactor as a result of operation of the ESCR discussed previously.

Then the city of Piqua, and that is on page 20:

The city of Piqua they are going on with the construction except that there was testimony given that a container might be required and that would cost several hundred thousand dollars, and it might in some degree change the Piqua operation.

The third one you mentioned is Puerto Rico, and that is not in the authorization bill. The box score would be no runs, no hits, no errors.

Mr. MORRIS. On the Nebraska one, we certainly would not interpose a separate viewpoint from the negotiations between Nebraska and the AEC to work out the best solution.

Chairman ANDERSON. The testimony was that the AEC had suggested the postponement. We are going to try to get the Nebraska people in to try to find out how they feel about it. I think it is proper. I would like to see it go ahead, but it may not be ready.

Mr. MORRIS. I think we have no different view on that.

Representative HOSMER. Would the same thing be true if it were found out that it required a container and the cost of the container is such that the economics of the plant would be affected in relation to the city's ability?

Mr. MORRIS. On the basis of the Piqua proposal, I would expect that this matter of the container would be a matter of negotiation between the AEC and Piqua and not necessarily placing the sole burden upon the utility.

Representative HOSMER. Whatever part of the burden that the utility might have to accept would be a consideration in its willingness to accept the price tag.

Mr. MORRIS. That is correct. Certainly I would not interpose any technical viewpoint which would not be consistent with a safe reactor being built.

Representative HOLIFIELD. Mr. Morris, I want to refer to page 4 of your statement, your comment on the department of water in the county and city of Los Angeles. As you probably know, a part of the city of Los Angeles served by the department of water is in my congressional district. So I have some direct interest as well as general interest in this subject. I would like to ask you at this time, if under the charter of the Los Angeles Water Department they could participate in a capital grant subsidy as has been proposed and requested by the Commission, substantially on the basis that a private company could participate? I think you are aware of the formula, that it would be a formula that would cost them more to produce kilowatts than a conventional plant. The point of the question is, are they or are they not in a different legal position? Do they have reserves or ability to obtain funds where they can participate in that type of program, which I think I proved is barred to the other types of REA co-ops.

Mr. MORRIS. I should say that type of contract would have to be such that the general manager could recommend, and the board of water and power commissioners could find, that this was an economically desirable contract to proceed upon.

Representative HOLIFIELD. Economically desirable? Does that mean it would have to be at or near the range of competition with a conventionally powered plant?

Mr. MORRIS. I should say reasonably so. They could interpret some other advantages. We are having, as you may know, some smog problems and so forth out there, and we are under some restrictions on the use of fuel oil. So we really have a real reason for going in and trying to develop atomic power even beyond the normal one which we have had because of problems incident to the burning of fuel oil.

Representative HOLIFIELD. In other words, you feel that there are some peculiar atmospheric conditions out there which are causing us trouble, which might constitute a legal justification for participating in this kind of a program even though it might not be competitive from a conventional standpoint?

Mr. MORRIS. I think so, within reasonable limits.

Representative HOLIFIELD. But it would have to be very close, would it not?

Mr. MORRIS. Yes; fairly so.

Representative HOLIFIELD. It would have to be within the range of a very few mills. It could not be in the range of the difference between 6 or 7 mills and 25 mills or 30 mills.

Mr. MORRIS. Yes.

Representative HOLIFIELD. It would have to be within a few mills.

Mr. MORRIS. Within reasonable limits; a few mills, not a lot of them.

Representative HOLIFIELD. Otherwise as a municipal plant you, too, would be barred from this type of program.

Mr. MORRIS. I should say so.

Chairman ANDERSON. When he refers to peculiar atmospheric conditions, he could not have meant "smog"?

Representative HOLIFIELD. I was trying to keep that word out of the record.

Mr. MORRIS. I used "smog" myself. You may know the Los Angeles County Air Pollution Control District has passed a regulation which provides for 5 months of the year we shall either burn natural gas or burn fuel oil not to exceed a half a part per million of sulphur. There is no domestic oil of that nature which means we must burn gas exclusively, and we don't know whether we can quite do that or not. That applies not only to ourselves, but other privately owned utilities and municipalities in the same area.

Chairman ANDERSON. I know where the natural gas is coming from now. I think that is a very wise ordinance.

Mr. MORRIS. I am concerned with this, Mr. Chairman. I read in the paper as I was in transit here that there was a proposal to build a new pipeline to southern California to bring in more gas, and it was being opposed by a large organization in California that did not want this additional pipeline.

Representative HOSMER. I just want to say that I am very happy to see my distinguished Californian before this committee today.

Mr. MORRIS. Thank you.

Chairman ANDERSON. I think we all are, Mr. Morris. Mr. Bates?

Representative BATES. Under section 110, under that $30 million, you would be able to get into a program, would you not? The new authorization bill that Mr. Holifield referred to?

Mr. MORRIS. I don't know the technical details.

Representative BATES. I will ask the staff director for the committee, is that a correct statement?

Mr. RAMEY. I think the Commission indicated that of the $30 million, they were proposing for this program, it could include grants for a small reactor, so-called, that could be built by a publicly owned organization. I think this is the implication of their statement.

Representative BATES. Thank you.

Chairman ANDERSON. Thank you very much, Mr. Morris. Come back frequently. We are always happy to have you.

Mr. MORRIS. Thank you.

Chairman ANDERSON. Our next witness is Mr. Theodore Marvin, president of the Michigan Chemical Corp. We are happy to have you here, Mr. Marvin, and you may proceed.

STATEMENT OF THEODORE MARVIN, PRESIDENT, MICHIGAN CHEMICAL CORP.; ACCOMPANIED BY DR. ADRIAN GAMMILL, DIRECTOR, RARE EARTHS AND THORIUM DIVISION, ST. LOUIS, MICH.

Mr. MARVIN. Thank you, sir.

Mr. Chairman and distinguished members, I want to point out first that I am only a metallurgical and mining engineer from Mr. Aspinall's district, and I am not a nuclear engineer. I do have my associate here who has a consideral nuclear background, and who can help on technical questions.

It is a pleasure to appear before this distinguished committee this afternoon to discuss utilization of nuclear energy to produce process steam. This application of nuclear energy has largely been neglected or bypassed because of the seemingly greater potential of nuclear energy in electric power generation.

Michigan Chemical Corp. has had a study underway for several years to determine the most economical and practical way to produce process steam at its St. Louis, Mich., plant. During the past year, this study has led us to a comparison of the nuclear process steam-plant with a similar size fosil fuel plant. Assisted by our nuclear specialist, Dr. Adrian Gammill, it is my purpose to discuss here some of our findings regarding this study and our recommendations.

Firstly, let me review the steam requirements for our St. Louis, Mich., plant which we believe are similar to a large number of chemical and other industrial plants. At present our process steam cost from oil-fired boilers is approximately $0.90 a thousand pounds. Admittedly, this is high compared to giant size producers who can get fossil fuels in volumes at lower prices; our cost also is high as compared to large and small producers located closer to fossil fuel sources. At our plant, steam is used for a wide variety of chemical processing applications as well as for operating equipment, and for general heating purposes. Some 75 percent of the total steam generated

is ultimately reduced to five pounds pressure and is used to evaporate natural brine feeds in the manufacture of an extensive series of chemicals such as bromine and magnesium compounds. I might add also in this reduction down to five pounds we pick up via turbine about 20 percent of our electrical needs. Our projected requirements for steam in the foreseeable future amount to around 150,000 pounds an hour at 150 pounds to 200 pounds pressure. This amounts to about a billion pounds per year.

While we have no definite need to displace our present facilities, we have discussed a new steam plant with a number of companies which fabricate fossil fuel plants and during the past year, we have talked with most of the nuclear companies which have expressed interest in the design and construction of nuclear steam units. Two nuclear companies submitted generalized quotations on nuclear process steam plants capable of producing 150,000 pounds of steam an hour at the required 150 pounds to 200 pounds pressure.

Besides the data offered in these proposals we also have derived a considerable body of information through our independent study of nuclear steam plants. Our report entitled "A Study and Recommendations for Manufacturing Process Steam by Nuclear Energy," which each of you has received, contains detailed comparisons of nuclear fuel plants with a fossil fuel plant.

Our study was aimed at the relative economical and technological comparisons of nuclear steam plants and fossil steam plants. In this respect, it should be kept in mind that the chemical business is a highly competitive industry and that steam plants, as important service facilities, must produce steam so that end products will be competitive.

Cost of steam from a fossil fuel plant is obviously known through years of operating experience. On the other hand, cost of steam from a nuclear steamplant can only be estimated by projected technology. Since a nuclear steamplant has never been built, it presents a rather high degree of uncertainty as to what its exact capital and operating costs will be. In a relatively high cost fossil fuel area such as St. Louis, Mich. (a condition encountered widely throughout the United States), the projected cost of a nuclear steamplant under certain conditions approaches competitiveness with a fossil fuel plant.

However, without firm costs, which in turn would mean uncertainties in return on investment, we would of necessity choose the equipment in which firm capital cost and operating cost are known. Should we need to displace our present facilities, this in turn would dictate the installation of a fossil fuel plant until such time that firm costs of a nuclear steamplant are known. This would simply be a matter of good business judgment since stockholders of a corporation expect management to assure them of a reasonable return on investment. Our studies, though, encourage us to support the opinion that the technology and economics of the generation of steam by nuclear energy hold promise and should be pursued.

By way of comparison, allow me to quote some of the data that we have compiled: A new coal-fired steamplant capable of producing 150,000 pounds of steam an hour at 150 to 200 pounds pressure would cost from $1,500,000 to $2 million. Taking a steam production rate of one billion pounds a year, the cost of steam from the coal-fired plant would be $0.83 a thousand pounds. One nuclear steam

plant about which we have some general data was priced at $3,300,000. The cost of a thousand pounds of steam from this unit is estimated to be $1.04. If we assume that the nuclear steamplant cost only $1,500,000 or the same as the lower cost coal-fired plant, then the cost of nuclear steam would be $0.76 a thousand pounds. This figure, of course, is to be compared with the $0.83 a thousand pounds from the coal-fired plant. The above nuclear steamplant cost is based on $30 a gram plutonium credit and no uranium use charge. Lower plutonium credit and a use charge would obviously increase the $0.76 figure mentioned above. In our report we cite other comparative nuclear fuel cost which range up to $1.25 a thousand pounds, and which are based on different types of plants and on different operating conditions.

Chairman ANDERSON. May I stop there to ask you if you move that plutonium credit to $12 a gram, what would that do to your cost of steam?

Mr. MARVIN. I think it moves the $0.76 figure up to about $0.86.

Chairman ANDERSON. And if you put in the uranium use charge, what would it be?

Mr. MARVIN. $0.08 on top of that or $0.94:

Chairman ANDERSON. So that your final cost would come up to a little higher than the regular fossil fuel charge even if you cut the price of the plant in half.

Mr. MARVIN. As we know it now, yes.

Normally a fossil fuel steamplant would be depreciated over a 20-year period since one could reasonably expect such a life from this type of plant. However, depreciation of the nuclear plants in the above figures is predicated on a 10-year period and even this figure may be too high because of likely rapid obsolescence. The previously cited report, of which you have received copies, contains cost data based upon various conditions of plutonium buy-back policies, uranium use charges, amortization, etc.

You will note that the projected differences in cost of steam, using fossil fuel and nuclear fuel differ by reasonably small percentages. This is in considerable contrast to the power industry where the difference is orders of magnitude. The reason for this is the relatively low pressure, low temperature steam required for processing needs. This means that much simpler equipment can be used throughout the reactor and that safety requirements can be reduced markedly over high temperature, high pressure reactors. Fuel element costs will be materially reduced since aluminum-clad fuel elements in place of zirconium or stainless-steel clad elements may serve this purpose adequately. Following the normal course of events, the capital costs should be reduced materially and operating costs should materially improve after two or three such reactors are built and operated.

In view of the projected relatively small difference in the costs of steam from nuclear and from fossil fuel plants, we believe that the first competitive nuclear power in the United States will be via nuclear steamplants. Since more steam is used for process heat than for other purposes, this means that potentially this area offers an extensive utilization of nuclear energy. It also should be remembered that most nuclear steamplants probably will be relatively small (50 to 100 thermal megawatt sizes). This in turn would mean that many

more reactors might be installed by virtue of size consideration alone. There is another factor of importance concerning the nuclear steamplant. It can be adapted to isotope production. We have given this phase of the program considerable thought and it seems reasonable to conclude that the relatively small additional investment involved could result in the adaptation of the reactor to isotope production. This, in turn, would help defray some of the operating costs and, if the isotope market permitted, it could result in a further lowering of steam costs.

The question may well be asked, "Well, why hasn't the chemical industry recognized the nuclear process steamplant and done something about it?" I refer back to my earlier comments regarding the fact that a steamplant is a service facility and not a primary production facility as is true of the utility industry. We believe that if firm capital and operating costs are established for process heat reactors, and that if these costs demonstrate competitiveness, a sizable market will develop for nuclear process steamplants.

To effect this demonstration program, we believe the Commission should broaden its third round demonstration program to recognize the conditions where process steam is used that are different from the conditions that exist in the power industry. Since we are really talking about a prototype unit here, the total investment is relatively small. Having been here yesterday, Mr. Chairman, my definition of a prototype unit is a reactor which is the first of a kind, but one which is of useful and practical nature.

We invite the Commission to build such a facility at our St. Louis, Mich., plant and to permit us to operate it. This would establish firm capital and operating costs under conditions that would prevail under normal usage. Our more detailed report contains suggestions of how this might be accomplished. We believe that this demonstration program can be carried on with a very small total dollar expenditure and that it will materially advance the nuclear industry.

For a chemical company, at least of our small size, to undertake the building of an initial reactor would mean that the company would be faced with uncertain capital costs, uncertain operating costs, and possible rapid obsolescence. This is not an attractive venture as such. Therefore, it is recommended that the Commission participate more fully in this area to the extent of building two or three nuclear steamplants in such a time sequence that knowledge gained from one can be applied to subsequent ones. Michigan Chemical Corp. is interested in aiding this program and would be agreeable, under certain conditions, to provide the plant site, the operating application, and the management of the project. In effect this would amount to our subsidizing a Government action which is somewhat the reverse of the usual procedure.

Thank you very much for the privilege of being before the committee.

Mr. Chairman, may I add here that I have a very encouraging letter, dated February 6, 1959, which I feel I should call to your attention from Dr. Frank K. Pittman, Director, Division of Reactor Development, of the U.S. Atomic Energy Commission. It was sent over the signature of Dr. A. J. Vander Weyden, Dr. Pittman's associate. May I read parts of this letter?

Chairman ANDERSON. Yes, surely.

Mr. MARVIN. He acknowledges our report, of which we had sent copies of the Commission, and he said:

> In general your analysis of the present situation of nuclear process heat agrees with our own appraisals. While it is true that this area has been comparatively neglected until now, the Atomic Energy Commission has recently sponsored two market surveys of the process heat industry, and at present is employing a group of leading scientists and engineers at one of our national laboratories to study the various concepts in order to determine which is particularly suited for generation of process heat. As a result of these studies we hope to insure that the reactor which is best suited for nuclear process heat is the one which receives Commission support. An engineering analysis such as the one you have submitted to us would be extremely useful to this group. With your permission we will forward a copy of the report to this evaluation group.

Of course, I was happy to write to Dr. Vander Weyden and to give him full permission to use anything we have in this respect which may be helpful.

Chairman ANDERSON. The committee is happy to hear of your goal that there may be a process heat plant constructed. I think your reference to Mr. Aspinall would make it appropriate for him to start the questioning, if he desires to do so.

Representative ASPINALL. Mr. Chairman, I have but one question of the witness. I may say that I am most pleased to see him before the committee. How much of your own funds, Mr. Marvin, have you spent in the studies that you have made to date?

Mr. MARVIN. We started about 3 years ago to conduct a study on getting more efficient steam for our processes. We proceeded through the next 18 months studying fossil fuel units employing oil and coal. As we proceeded on the investigation we were not too encouraged by the likelihood of possible increases in the costs of fossil fuels up in our section of the United States and the subject of nuclear fuel was thereby injected into the situation, principally by our own nuclear personnel. We already are in a phase of nuclear activity through the manufacture of rare earths. This interest led us to discuss a nuclear-fuel steam-process plant with different companies. With such nuclear specialized firms and through our own research, we carried on an intensive study over the next 18 months. The essence of these investigations was continued in the report which the committee received.

In money, I would say we expended from $25,000 to $50,000, which to us is a considerable amount. We are continuing our study in the hope that when the time comes when we need to displace what we have today to produce steam with another type of unit, we hope that there will be data and firm costs available that would very possibly permit us to operate a nuclear plant at St. Louis, Mich. This could be with participation by the Government and/or with participation by some of the nuclear companies. We do firmly believe that we do have a good "guinea pig" situation for a nuclear fuel process heat unit.

We would use the steam from the plant; we would provide a site; we would provide the operating application; and we would provide the management. In these respects, therefore, it would be a practical operating unit from the beginning.

I was delighted to see in Chairman McCone's report yesterday that the AEC has indicated that it is going to build a unit, a position somewhat indicated in Dr. Pittman's letter which I read.

Representative ASPINALL. Thank you, Mr. Chairman.

Representative DURHAM. Mr. Marvin, of course you are nearer operating costs here than we were when we started out with power. This is encouraging to me. At the present time is there any other company doing such a study on process steam as your company?

Mr. MARVIN. I don't believe so. The Manufacturing Chemists' Association, of which we are a member, has appointed a committee on atomic energy and a phase of that committee's work has been an investigation of the use of atomic energy fuel for steam. That study is just getting underway. Dr. Gammill sits on that committee, and we have provided to that committee all of our facts. But I do not know of another chemical company—it may be rather strange—which has been doing any real work on the subject.

Representative DURHAM. Is the chemical industry the largest user of process steam?

Mr. MARVIN. I would say it is larger than the paper industry which is the other probably very large user. I do not have such facts at hand, but I would think that the chemical industry is the largest user.

Representative DURHAM. It is quite extensive?

Mr. MARVIN. Very extensive; yes. It should seem to be a "natural" if we could achieve this first breakthrough.

Representative DURHAM. I want to congratulate you on your study because I have always felt that this is one field in which we could develop further in the future. I think it is going to grow instead of diminish. Certainly the paper industry is still growing.

Mr. MARVIN. We did submit, in June in your hearings, the beginning of this project to Mr. Holifield, and Mr. Holifield did have our data entered into your record at that time. I think that was probably the first public reference to this division of nuclear energy that has been made. It has been kind of a "lone wolf" project on our part. Again I am delighted to see the letter from the AEC that the subject is being reviewed, and also that Mr. McCone included it in his report yesterday.

Representative DURHAM. Your own industry is still a young industry in America.

Mr. MARVIN. Yes. I think we probably will get various chemical groups to take a greater interest in the program outlined.

Representative DURHAM. Being somewhat connected with that field, I can remember when all the work came from some other part of the world.

Mr. MARVIN. That is right.

Representative HOSMER. Mr. Marvin, can you take your heat off the primary circuit, or do you have to take it from a secondary circuit?

Mr. MARVIN. You are getting out of my field.

Dr. GAMMILL. It is actually the secondary circuit which will contain heat exchangers and which will be a source of steam.

Representative HOSMER. Could you use primary steam for some operations?

Dr. GAMMILL. You probably could, but the trouble is that the possibilities of a fuel element failure might throw radioactive material into the circuit; this could pose problems. Until that phase is gone into more in detail, I don't think we would want to do it. In the fine chemicals division of our business, it would be impossible to do so.

Representative HOSMER. Mr. Marvin, you invited the Commission to build a facility out there. How much more than $0.83 a thousand pounds could you go on this operation if such an invitation would be accepted? You don't anticipate getting steam for nothing?

Mr. MARVIN. No. In the initial presentation of this subject that we sent——

Representative HOSMER. That won't be in this record.

Mr. MARVIN. That is all right. In the presentation we sent to Mr. Holifield, we indicated that our cost is 90 cents. If after getting one of these plants underway—and maybe not with the first unit as an example—if the costs get down under 90 cents, we said that we would be very glad to buy the nuclear reactor through any savings in steam that there might be. Some of the nuclear representatives have indicated that there is a possibility of getting steam—I don't want to put them on the spot—let us say at $0.60 subsequently. Certainly in high fossil fuel areas where steam does cost up to $0.85 or $0.90 one ultimately should be able to buy back or amortize a nuclear fuel plant under reasonable conditions.

Representative HOSMER. I understand the general situation. What I am trying to get is specifically this: You are not one of the giants in the chemical field.

Mr. MARVIN. No, we are quite small compared with them.

Representative HOSMER. Unlike the giants you have expressed an interest in this field.

Mr. MARVIN. Yes. On the point that you make, we would pay somewhere around our present cost to the Government for the steam.

Representative HOSMER. I tried to get your economic compulsion behind this and the degree of that compulsion from the private enterprise standpoint.

Mr. MARVIN. If I understand your point, again we would support a plant, if it were placed there, and pay somewhere around our present steam cost.

Representative HOSMER. Which you have not indicated for the record, and you don't need to, unless you want to.

Mr. MARVIN. I think we have indicated it when we submitted this to Mr. Holifield. I would include it.

Representative HOSMER. I do not believe it is going to be in the record. I am trying to make this record complete. If you do not want to reveal the figure, you do not have to. If you do, I would like to have it.

Mr. MARVIN. I don't mind having it included, if that is what you mean.

Representative HOSMER. What is it?

Mr. MARVIN. I cited today that our present cost is $0.90.

Representative HOSMER. I thought the 93 cents per thousand pounds was on the basis of the new plant.

Mr. MARVIN. No. I cited in my testimony there that our costs at the present time are 90 cents. I am sorry.

Representative HOSMER. Thank you.

Representative DURHAM. Are there any further questions? If not, thank you very much, Mr. Marvin.

Mr. MARVIN. Thank you, sir.

Representative DURHAM. The next witness is Mr. Auchincloss, Tracerlab, Inc. We are very glad to have you with us, Mr. Auchincloss. You may proceed with your statement.

STATEMENT OF SAMUEL S. AUCHINCLOSS, PRESIDENT, TRACERLAB, INC., WALTHAM, MASS.

Mr. AUCHINCLOSS. Thank you, Mr. Chairman. I would like to express my thanks for being asked to come to testify here today. I should like to make it clear immediately that I am speaking today for Tracerlab as a member of the applied radiation industry. Our business is not at all like the nuclear power business. The problems of our industry are vastly different in scope, magnitude, and financial import from those of the power industry, where the cost of one single powerplant run by nuclear energy may be easily greater than the total sales for a whole year of the entire industry of which Tracerlab is a part.

Tracerlab is the oldest company in the nuclear instrument and radio chemical business and enjoys the distinction of being the largest in terms of plant, people, and dollar volume. We are literally the giant of our industry by virtue of the fact that we do some $10 million worth of business a year, a mere bagatelle, gentlemen, in comparison with the savings which result for American industry from its use of the kinds of equipment we sell. In an address in Geneva, Dr. Willard Libby reported that the National Industrial Conference Board studies now underway indicate the current rate of savings to be hundreds of millions of dollars a year. In effect this means that the savings produced from the application of isotopes developed by companies like ours may recover almost half of the cost of operations in 1958 for all the activities of the Atomic Energy Commission. These savings more than paid for all the uranium procured, all the research and development costs of power reactor experiments, aircraft propulsion reactors, naval propulsion reactors and a number of other important programs sponsored by the AEC (1958 Annual Financial Report, U.S. Atomic Energy Commission Uranium Procurement, $558,500,000; power reactor experiments, 71.5 million; aircraft reactor research and development, $78,500,000; naval propulsion reactor research and development, $82 million). But, gentlemen, these savings are only a fraction of what they ought to be today and unless we take steps to assure more widespread industrial utilization, we will continue to achieve only a part of the benefits we should be getting.

In essence, the application of isotopes which is the flea power of atomic energy is supporting the horsepower of atomic energy but we are only scratching the surface in isotope applications. In 12 years, for example, there have been only some 4,000 licenses issued to isotope users. Why such reluctance?

The applied radiation industry certainly doesn't lack for talent to develop new ideas for industry. We have always been able to attract top quality scientific people. As a matter of fact, we might observe that many of these people have found the incentive to set up businesses of their own in order to capitalize on their technical skill in isotope applications. In 12 years, some 20 Tracerlab trained people have become presidents of companies in the nuclear and allied fields developing these very moneysaving techniques.

Our industry certainly has the ideas and with the support of the Atomic Energy Commission program to develop industrial applications, we have proved that we can produce a wealth of useful practical applications. As a result of this program, Tracerlab itself during the last year has engineered and will introduce commercially an air pollution monitor employing advanced radioisotopes techniques.

Almost all the companies in our field are making modest profits; however, substantial amounts from our limited funds have been plowed back into additional development. There has, however, never really been nearly enough money left over to effectively educate the potential users of these applications so they understand how the savings are achieved. Top management, the management that makes the decisions for capital investment, doesn't usually have the technical understanding that leads to full appreciation of the potentials of isotope application for their business. They want to be shown; they want concrete proof. In addition to this, many of the companies who have invested in moneysaving isotope equipment jealously guard their use of it as a trade secret, further restricting the spread of information on the subject.

Another point is that so much emphasis and public attention has been focused, quite rightly, on radioactive dangers that many are afraid of the whole subject and wish to do no experiments. In this connection I wonder what would have happened if that new, mysterious, unseen, unsmelled, unheard, and deadly force electricity had been ushered into the world with the same type of publicity which has been the lot of atomic energy; 110 volts can kill, gentlemen. Would the U.S. Electricity Commission circa 1905 allowed its use in houses without a license?

Worst of all, gentlemen, the isotope application industry is made up of dozens of firms, many much smaller than ourselves, most of whom do not have the capability or money to properly promote their applications once they have been developed.

It is this problem which I want to discuss with you today. Why is it that these scientific principles which permit us to measure and control so swiftly and with such amazing accuracy are not actively adopted by management? Why are these properties similar to the ones which alchemists strove so hard to discover, not speedily employed by American industry at all levels with great diversification?

The answer is simple. American industry is still waiting to be shown and in our segment of the nuclear industry, we don't have the means or the money to show it.

It has become evident that for many applications the cost of development to the point of assured technical feasibility is small compared to the cost of demonstration of the economic justification of such application. I pointed out earlier that by virtue of the nature of our industry, with its many small companies, it has been impossible to undertake the essential final steps in a program of isotope application development, namely, the proof of economic soundness. This role logically falls within the scope of AEC's activities, and it is to the Commission that we must look to help us get more out of our industrial program.

The AEC already has a precedent in its activities aimed at demonstration of economic feasibility in its reactor development program.

This program is not merely one to develop optimal types of reactors, but it is also meant to demonstrate to the American people and the American power industry that nuclear power can be used as safely and as cheaply as other known power sources. We are actually demonstarting to what appears to be a reluctant industry that nuclear power is perfectly feasible. Why not do the same thing for isotope applications? Under our present program for isotope utilization, the AEC has sponsored many technical studies leading to reports on the subject or to the training of technical people through contracts frequently with nonprofit institutions and universities. The information available from these reports has been distributed generally to other technical people. Our own experience, however, indicates that this information is not getting into the hands of the management people who are responsible for decisions regarding capital expenditures in a form which leads them to take positive action. In substance, we are not getting through to enough of the people who should use isotopes and whose wider use of them could produce vastly greater savings than we now enjoy.

I propose, therefore, that this committee encourage the AEC to undertake immediately a broadened program to demonstrate economic justification of isotope applications along the following lines:

1. The Commission should select those industries in which proven techniques and equipment might be, but are not being, profitably used, and invite individual companies within these industries to submit proposals for justification studies utilizing such techniques and equipment in their plants.

2. The AEC should underwrite the costs of application engineering surveys in plants selected and purchase the necessary equipment from commercial sources. It is not intended that the program should support development of new types of equipment, but rather should have as its goal the application of well developed commercial devices and techniques to new situations.

3. All such studies must incorporate an objective cost accounting program utilizing standard cost accounting procedures for the industry involved to establish realistic and acceptable figures for savings achieved.

Each justification study would then be summarized at its conclusion in the form of reports to the AEC which would be made available to all members of the industry involved or of industries in related fields. These reports would be prepared in such a form as to be convincing and easily understood by both technical and management personnel—the Machinery and Allied Products Institute new equipment and analysis form is typical of this kind of report. It is obvious that many contractors will be sufficiently impressed with the value of such equipment to want to buy it. Should the contractor indicate willingness to purchase the equipment, he should certainly be allowed to do so at a fair market value, thus reducing the cost of the program to the Government. If the contractor does not wish to purchase, then the equipment remains Government property and may be used elsewhere.

I am sure that industry will cooperate with the AEC, and that trade associations and individual companies would actively assist in carrying out such a program.

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The values of this type of justification demonstration are:

1. Allowing the AEC to promote isotope applications in the manner outlined here would also hasten the liberalization of the controls which now govern all our nuclear activities and dispel more rapidly the remaining fears surrounding the atom in minds of the lay people.

2. The work would actually have been done by people who have the confidence of others in their industry or in related industries, and done in an actual plant under actual working conditions, so that the validity of the savings could not be questioned.

3. In many instances, a portion of the AEC's investment would be recovered, especially as savings became evident and offered proof to justify the purchase.

4. By going directly to the ultimate user and demonstrating the economic justification in his facilities, the time cycle can be shortened substantially since we avoid the time spent on hypothetical demonstrations in laboratories and other nonrelevant activities.

For example, we are aware that the copper industry has not adopted, to nearly the extent it could, the use of nuclear techniques. This is due to the fact that application of these devices to the processes of the copper industry has not been adequately demonstrated, nor are the economic benefits which might result from this application proven. Under the plan outlined here, the AEC would invite proposals from copper manufacturers for the installation of thickness gages, automatic process controls, and other nuclear devices in a producing copper plant. A period of cost analysis of the resulting savings from the use of this equipment would be carried out with good prospects of successful proof of justification. As a result of this activity, we believe that other copper producers would gain confidence in the potential savings and that a substantial new market would be obtained for the application of isotopes.

A great opportunity could be yours. If you continue to leave the demonstration phase of this job unfinished, we only delay needlessly the chance to add those other hundreds of millions in savings in raw materials and reduced scrap that we should have been enjoying 2 or 3 years ago.

If you act now to provide the AEC with suitable encouragement and the relatively modest funds to conduct such a demonstration program for isotope applications as you now have for nuclear power, we can convince management of the validity of our claims more quickly.

Let me remaind you in closing that it is only the flea power of the atom which will produce the tremendous savings we look for now. The fractions of pennies saved on yards of plastic sheet in one plant will inexorably add up to thousands of dollars during a workweek in which miles of it are produced. The same is true for the tons of paper, the millions of tires, the billions of gallons of oil, and the thousands of tons of metal we turn out under America's mass production techniques. I for one don't want to look back on 1959 as another year in which we neglected to make the modest investment which could produced the long awaited billions in savings.

Chairman ANDERSON. This is a very interesting proposal. I am glad that business makes it. If some members of this committee proposed that Government money be spent to go out and develop a

market for a private corporation like that, they would be accused of being close to socialistic. But if it comes from a businessman it is perfectly all right. I am very interested in the suggestion you make. I see you suggest that we go to the AEC and provide them with encouragement with modest funds. I think we will have to wait until they come to us on this question of funds, but the proposal is very fine. I really believe that the work of isotopes is the most fruitful field that atomic energy now has. It certainly is paying a very fair rate of interest on all the investments that have ever been made in the whole field of atomic energy and anything that helps it along is fine.

Are there any questions?

Representative DURHAM. Pursuing that thought further, Mr. Chairman, this is what we though we were doing when we adopted the 1954 act, which we worked over and sweated over for months and months. It was for the purpose of enabling you to get all this information. The main complaint seems to be at the present time that people are not trying to get the information they need regarding the use of isotopes.

Mr. AUCHINCLOSS. Yes. I think they are getting the technical help. I think we need education in the economics of the situation to a further extent. I think the technical people are fully aware of the potentialities of the use of radioisotopes.

Representative DURHAM. I think I agree with you on that. The problem is what? Do you think it is the responsibility of the Federal Government or the responsibility of industry since Congress did provide means and measures whereby you could get this if you asked for it?

Mr. AUCHINCLOSS. I think the means are technically available. I think it is a matter of the encouragement of AEC to make use of them when they may feel that under certain sets of circumstances they are dealing too much with individual people to achieve the end instead of with broad sections of the industry. The textile industry is a case in point. We have actually offered to give to the textile industry equipment, but they won't take it as a gift. I mean a loan, rather. It is because they fear the cost of studying the use of it.

Representative DURHAM. The textile industry in my State went out and set up a laboratory.

Mr. AUCHINCLOSS. That is right.

Representative DURHAM. They buy their equipment in Canada because they cannot get it in this country.

Mr. AUCHINCLOSS. That was the university, was it not?

Representative DURHAM. That is right.

Mr. AUCHINCLOSS. It is the individual industry we have had trouble with.

Representative DURHAM. They paid for the laboratory completely out of their own money and didn't ask anybody for anything. That is an approach which I think is not being generally applied throughout the country.

Mr. AUCHINCLOSS. That is right. That is an advanced approach.

Representative DURHAM. I do not know what type of equipment you make. I know of your company. Do you make all types of equipment?

Mr. AUCHINCLOSS. A very wide line of nuclear measuring equipment including beta gages and so forth.

Representative DURHAM. Are you making this type of machine which is primarily designed to study radiation on cloth and all types of material?

Mr. AUCHINCLOSS. Yes, sir.

Representative DURHAM. You are making those?

Mr. AUCHINCLOSS. Yes, sir.

Representative DURHAM. I do not know why they had to go to Canada to get it if it is made in this country. But they did go to Canada to get it.

Mr. AUCHINCLOSS. We are making an industrywide appeal here and not for Tracerlab alone. We are making it for further knowledge in the use of isotopes and the economics.

Representative DURHAM. Do you not agree that hospitals today are making great use of radioisotopes?

Mr. AUCHINCLOSS. A very great use, Senator. The hospitals are technical people and they understand this. We sell it to them on a technical-person-to-other-technical-person basis.

Representative DURHAM. Who is your biggest customer, the hospital or the medical profession?

Mr. AUCHINCLOSS. We do about 40 percent of our business with the medical profession.

Representative DURHAM. I agree with your statement, of course. They are probably not taking advantage of what we have developed in this country and which is available at the present time. To do the job of educating the people I think is the responsibility of the universities and the manufacturing industries who desire to do this type of work. I don't like to see my Government getting any further into the field of education. It has caused us enough trouble already. I think that is one thing that should remain with the people, just as freedom of expression in universities, which I think should always exist.

Chairman ANDERSON. Senator Dworshak.

Senator DWORSHAK. I am a little intrigued with your statement on page 3 where you emphasize the need of using the full potential of isotopes in application to business. You say, "They want to be shown, they want concrete proof." In addition to this, many of the companies who have invested in money-saving isotope equipment jealously guard their use of it as a trade secret, further restricting the spread of information on the subject.

What would you have this committee do about that?

Mr. AUCHINCLOSS. The only thing I am trying to do is to get some help from the AEC to demonstrate the economics of the use of isotopes as well as the technical feasibility of them. Broadly, not necessarily only in our own industry.

Senator DWORSHAK. It seems to me if any business which might have an application of atomic energy, such as in this instance isotopes, if they are lacking in the resourcefulness and initiative to utilize what is already available, I don't know that we can put a spur on them and force them to do something which they do not sense the need of doing for themselves.

Mr. AUCHINCLOSS. Aren't we doing it to some extent with the power industry?

Senator DWORSHAK. I do not know. You are complaining that they are not doing it. That is what I am trying to develop. Are you not saying that they are holding back, that there is too much reluctance?

Mr. AUCHINCLOSS. I think they are. We are finding it difficult to even loan instruments to some industries when we know that they can save money. They are reluctant to spend the necessary money to evaluate the loaned instrument. If we can get them in and help them in that evaluation program, I think the thing will mushroom very quickly. I don't think it is a big project. I don't think it is a lot of money. I think there are moneys already appropriated.

Senator DWORSHAK. You think it is somewhat of an educational process?

Mr. AUCHINCLOSS. Yes, sir.

Representative DURHAM. If the gentleman will yield at this point. I don't know whether you have read the AEC's current semi-annual report but starting on page 66 there are 10 pages devoted to progress in isotope development. In my opinion, the Commission has gone a long way in training people in isotope technology. As outlined in their semi-annual report they have quite an extensive program. This program is conducted both in universities and industry. I feel that the Commission has done a better job in this field than they have in some of the others.

Chairman ANDERSON. Mr. Hosmer.

Representative HOSMER. Has your company made any study of its expenditures for sales promotion as compared with roughly similar businesses?

Mr. AUCHINCLOSS. You mean the sales costs?

Representative HOSMER. Sales promotion costs.

Mr. AUCHINCLOSS. There is not very much information available in this industry on that subject, sir.

Representative HOSMER. What is that?

Mr. AUCHINCLOSS. There is not very much information on that subject in this business because there are no trade associations, and the people keep this pretty much to themselves.

Representative HOSMER. You do not know whether your percentage of cost allocated to sales promotion are big or small in relation—I can't say other competitors, but comparable types of business?

Mr. AUCHINCLOSS. It is very hard to determine that, sir.

Representative HOSMER. That is all.

Chairman ANDERSON. Mr. Bates.

Representative BATES. Mr. Auchincloss, I just wondered as you read your statement whether this reluctance on the part of some potential customers might be manifested through a fear of the unknown. In other words, this is something new, they are not accustomed to it and therefore they are suspect of it. Do you encounter that at all?

Mr. AUCHINCLOSS. No; I think that is a part of it.

Representative BATES. You think it is a major part of it?

Mr. AUCHINCLOSS. No; not a major part.

Representative BATES. I would think just from listening to you that most of your problem is a marketing problem that a good sales

manager could handle, unless there is that unknown present, that people are dealing with something that is entirely new and which might somewhat alarm them.

Mr. AUCHINCLOSS. I think there are two phases to it. One, there is a little fear of the medium, and there is also a disbelief in our claims.

Representative BATES. Do you think that something along the line of a seal, which we have on many products, might be of assistance? We have many things in the Pure Food Act which require approval. Therefore, it remedies the fear that people might have in their mind. Do you think that some sort of seal might be helpful?

Mr. AUCHINCLOSS. Do you mean different from the warning seal we now carry on the devices?

Representative BATES. I do not know what kind of seal you have. I mean a seal to indicate that the thing is safe and has been approved by the AEC.

Mr. AUCHINCLOSS. It would, if it were possible to do it, sir. Most of these devices do contain radioactive materials and they must, according to the rules of the Commission, carry the warning seal which is prescribed by the Commission. That is quite correct, I think.

Representative BATES. When you see a warning seal on there, that scares folks away. I mean something more like an underwriting seal indicating this has a stamp of approval for certain uses under certain circumstances.

Mr. AUCHINCLOSS. If we had that in addition to the seal it might be helpful. After all, you see 600,000 volts some place and then you see Board of Underwriters underneath, you get confidence that it is properly designed.

Representative BATES. That is all, Mr. Chairman.

Chairman ANDERSON. If there are no further questions, thank you very much.

Mr. AUCHINCLOSS. Thank you, sir.

(The following is correspondence relating to statements made by Mr. Auchincloss regarding the need for a broadened industrial program of isotope application development. See also additional correspondence, appendix 10, p. 629.)

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C., February 20, 1959.

Mr. A. R. LUEDECKE,
General Manager, Atomic Energy Commission,
Washington, D.C.

DEAR MR. LUEDECKE: Enclosed is a copy of a statement presented on February 19, 1959, by Mr. Samuel S. Auchincloss, president, Tracerlab, Inc., in the section 202 hearings currently being conducted before the Joint Committee.

On pages 5–9 of the statement, reference is made to the need for a broadened industrial program of isotope application development. The committee would appreciate receiving comments from the Commission and comparisons between the program suggested by Mr. Auchincloss and the isotope development programs presently in effect as described on pages 68–75 of the 25th semiannual report of the Atomic Energy Commission.

Thank you for your assistance in this matter.

Sincerely yours,

JAMES T. RAMEY, *Executive Director.*

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., March 10, 1959.

MR. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy, Congress of the United States.

DEAR MR. RAMEY: The Commission appreciates the opportunity to comment on the testimony of Mr. Samuel S. Auchincloss, president, Tracerlab, Inc., which was transmitted with your February 20 letter. The committee's interest in the isotopes development program is welcomed and gratifying. We hope the individual members share the sense of urgency, if you will, of our effort to accelerate the applications of radioisotopes and radiation throughout American industry.

While the Commission agrees with Mr. Auchincloss in recognizing the critical importance of stimulating management understanding of isotopes and radiation, we, nevertheless, must view this national development effort in somewhat different perspective. In pursuing our development program, we believe that there is a clear line of demarcation between Government and industry responsibilities for encouraging radioisotope utilization. Demonstration of applications already in profitable use throughout industry appears to be the normal responsibility of industry itself and, specifically, of the companies marketing the required equipment or instrumentation. A demonstration program designed to exploit methods, procedures, and systems, which have been adopted by certain segments of industry, appears to be well suited for aggressive sales promotion by private enterprise. In contrast, we believe the funds budgeted for the isotopes development program should be expended in advancing the technology and development of new radiation techniques and applications. Naturally, in the course of this major development effort, there will be a demonstration stage; however, this activity will be confined to the "new" technology and its application.

Despite our primary interest in pioneering of research and development, we are acutely aware of management reluctance to adopt radiation techniques. Accordingly, for the past year, we have taken an active role in sponsoring conferences and meetings designed to review the economic and management implications of radioisotope use and to examine specific applications in wide industrial use. Meetings have been held in Baltimore, Md.; Clemson, S.C.; Miami, Fla.; and Manhattan, Kans. Two additional management oriented meetings are presently scheduled: Atlanta, Ga., on May 11–12, and San Francisco, Calif., in December 1959.

Recognizing that stimulation of management interest would be fruitless if technical training opportunities were not available, the Commission has established a series of courses in industrial radioisotope techniques. The first industrial radioisotope course is presently underway at the Oak Ridge Institute of Nuclear Studies with students from a wide range of industrial organizations. The second course will begin on April 6 and applications have already been received from technical personnel employed by 20 major corporations. We also recognize the contributions which colleges and universities can make to this industrial training effort and have planned a series of regional training centers to bring industrial training close to its audience. The first regional program will be underway this summer at the University of California where three courses will be made available to industrial scientists, engineers, technical management, and the general management group.

The features of the Commission's industrial isotope development program outlined above are typical of efforts being made to bring the advantages of radioisotopes and radiation into clear industrial focus. Moreover, development of industrial applications is being encouraged on a broad basis in cooperation and contract work with private companies such as Tracerlab, universities, and research institutes. Through this many-faceted development effort, we believe that the Government is making a balanced and positive contribution to advancement of industrial radioisotope technology. To dilute this effort by demonstrations of techniques or instrumentation already developed and already in use by over 1,000 companies would not be consistent with the Commission's responsibility for exploiting the many benefits which can accrue from new developments in radioisotope and radiation use.

I trust that these comments will assist you.

Sincerely yours,

PAUL FOSTER,
Deputy General Manager.

Chairman ANDERSON. The next witness is Mr. W. Kenneth Davis of the Bechtel Corp. of San Francisco.

STATEMENT OF W. KENNETH DAVIS, VICE PRESIDENT, BECHTEL CORP., SAN FRANCISCO, CALIF.

Mr. DAVIS. Thank you, sir.

Chairman ANDERSON. We have had you many times as a witness for the Atomic Energy Commission, and we are glad to see you here for Bechtel.

Mr. DAVIS. I am here today under somewhat different circumstances.

Mr. Chairman, members of the Joint Committee, I am very glad to be here today. I am W. Kenneth Davis, vice president of the Bechtel Corp. of San Francisco, Calif., in charge of scientific and nuclear development. Before joining the Bechtel Corp. in August 1958, I was director of reactor development for the U.S. Atomic Energy Commission.

Bechtel Corp. are engineers and constructors and work both in the United States and abroad. Our work includes the design and construction of conventional steam powerplants, hydroelectric powerplants, and nuclear powerplants and related facilities as well as oil refineries, chemical plants, industrial plants, oil and gas pipelines, and various types of civil works. Our work is largely concerned with natural resources and energy.

We do not develop or manufacture equipment. In all fields including the nuclear field it is our policy to work with qualified developers and manufacturers so that we can provide the best and most economical plants in accordance with the desires of our clients.

The company has been active in the nuclear power field for 10 years—since we constructed the Experimental Breeder Reactor No. 1 at Idaho and the Idaho Chemical Processing Plant for the AEC.

The company was a participant in one of the four original industrial study groups in 1951 and since has been active in the nuclear power group, which is an outgrowth of the original study teams. At the present time we are involved in the following major nuclear work:

1. Design and construction of the Dresden Nuclear Power Station for General Electric and Commonwealth Edison. Design work is essentially complete and construction is more than two-thirds completed.

2. Prime contractors for design and construction of Humboldt Bay No. 3 Unit for Pacific Gas & Electric Co. Detailed design of this 50/60 EMW boiling water reactor plant will commence shortly.

3. Contractors for the AEC on the design of the steam supply portion of the Hallam Station for the Consumers Public Power District of Nebraska.

4. Prime contractors to the AEC on a design study of organic cooled reactors.

5. Prime contractors for engineering and construction of the proposed high temperature gas-cooled reactor for Philadelphia Electric Co.

In addition to this work we are carrying out work on facilities such as hot cells and laboratories, have proposals outstanding for other nuclear projects, and are making studies of nuclear plants for clients.

I would like now to make a few brief comments on several points which seem pertinent to us in the subject matter covered by the Joint Committee's "Proposed Expanded Civilian Power Program" and the report of the AEC's ad hoc committee on reactor programs and policy.

DEVELOPMENT SCHEDULE

There are a large number of feasible and possibly attractive combinations of coolants, moderators, fuels, and physical arrangements for power reactors as well as variations and adaptations of these combinations.

Limitations of money, manpower, and facilities necessitate a selection and a determination of the effort to be expended in pursuing each of the concepts or variants chosen.

Criteria for making such selections are easy to arrive at but are often most difficult to apply, particularly in the early development stages of a concept.

The point I wish to make is that more consideration should be given to scheduling of reactor developments over a substantial period of time in phases rather than attempting to pursue each and every potentially desirable development on a large scale at the same time.

Such a long-range plan should concentrate on achieving economically useful nuclear powerplants of the now more developed types in the relatively near future; attaining improved efficiencies and economies, both from the nuclear and dollar point of view in the intermediate term; and achieving breeders and other types of very advanced reactors in the long term.

This is not to imply that substantial work should not be carried out at present on the intermediate and long term reactors, particularly of a basic or exploratory nature. It should be—and would appear to be—the particular area of responsibility of the National Laboratories.

However, it has been my belief for a considerable time that first priority and emphasis should be placed on the more developed types which appear capable of becoming economically useful in the near future. As effort on these is successful the priority and effort can be shifted to intermediate term reactors.

ATTAINMENT OF ECONOMIC NUCLEAR POWER

We at Bechtel are perhaps somewhat more optimistic about the time required for nuclear power to become economic in some parts of the United States than some of the recent Joint Committee and AEC program studies have been.

In setting goals in terms of time one must, of course, recognize them as an evaluation of prospects rather than as dates which can be set arbitrarily. Further, one must define what is meant by a particular date since several years will elapse between taking a decision to build a plant and having it in operation and still more time will pass before the plant may actually be demonstrating economic opera-

tion, particularly if this must involve a demonstration of the life of plant components as well as the life of the fuel charge.

There are thus two dates which seem to us to be of considerable significance. The first of these will be the date at which a forward-looking utility can decide to proceed with the design and construction of a large nuclear powerplant with confidence that it will prove to be economic over its useful life, even though it may not be economic during initial operations.

At this point progressive utilities will undertake nuclear powerplants. In our view this time may be within the next 2 or 3 years for high fuel cost areas where power is needed in large blocks. Such plants would be completed and commence operation about 1965.

The second important date is the time at which plants which have gone into operation have passed through their initial operating period and are able to show operating costs which demonstrate that the plants are economic.

At this point utilities generally should initiate construction of nuclear powerplants where conditions are otherwise favorable. This point appears likely to be achieved about 1968 or 1969 in high fuel cost areas. This second point, of course, will only be reached if plants are built which can provide the demonstration of economic operation or wholly convincing projections of costs to economic operation.

INDUSTRIAL PARTICIPATION

We are in agreement with the objectives of the civilian power reactor program as generally stated by both the Joint Committee and the AEC and with the necessity of the AEC maintaining leadership of the overall program to insure that the objectives are attained.

However, we believe that there should be a more clearly defined way in which civilian industrial developers, manufacturers, engineers, constructors, suppliers, and utilities can play an effective and continuing role in determining the program.

Committees such as the ad hoc committee are useful for advising on policy and should be utilized. Other types of AEC-industry arrangements should be made for technical decisions.

Perhaps it requires some emphasis that the objective of the program is to develop nuclear powerplants which will, in fact, be utilized by operating utility systems. They must be satisfied that the plants they will buy from the manufacturers and engineers will be efficient and safe, that they can be operated and maintained readily and safely, that they will be reliable power producers, and that they will have a long, useful life—25 or 40 years. These are all factors involved in a truly economic plant.

The plants developed in the civilian power reactor development program must meet the requirements of utilities and be acceptable to them or they will not be utilized and thus, will not be of value for electric power production regardless of whatever other virtues they may have.

We believe the AEC should have authority to carry out a flexible program covering all of the areas of activity necessary to attain the goals set. However, industry should also have an opportunity to exercise initiative in carrying out development projects including the

construction of prototype power reactors with consideration for research and development assistance even though industry initiated the project rather than the AEC.

The recent change in the ground rules for the power demonstration reactor program appear to make this difficult. Although it might be possible to convince the AEC that they should invite proposals for the type and size of reactor of interest to an industrial group this seems a cumbersome and uncertain procedure and not one likely to stimulate industrial initiative.

It is our firm conviction that prototype or larger nuclear powerplants should be operated by and be the responsibility of operating utilities rather than laboratories or nonutility contractors if they are to provide the technical and economic data as well as the operating experience desired.

It also seems essential that the design and construction of prototypes along with related development be carried out by manufacturers and engineers who can reasonably be expected to engage in the commercial applications of such reactors once developed.

DEVELOPMENT GRANTS

There has been considerable discussion in the past year about a program of grants as a means of providing assistance to prototype reactors and semicommercial nuclear powerplants which may be needed to bridge the gap between prototypes and the very large reactors which may be economic earliest. We would like to indicate our support for such a program of grants.

We would like to suggest one possible framework for determining such grants. An "allowable" nuclear powerplant capital cost would be determined in each case which would be the amount which could be paid for the nuclear powerplant which would allow it to make power competitively with a comparable size block of conventional powerplant capacity on the same system.

A grant would then be made under appropriate conditions for a fraction of the difference between the "allowable" nuclear powerplant cost and the expected actual cost of the nuclear powerplant.

A grant of something like 75 percent of the difference would seem reasonable in most cases but should receive further study. An AEC-Industry group might consider this matter along with the mechanics of such a program.

The operating and maintenance costs, including nuclear fuel costs, for the nuclear plant should be based on costs which are anticipated after the initial shakedown period of operation.

It might well be a requirement that the operating costs anticipated, and used for determining the allowable nuclear plant cost be at least as low as those for the comparable conventional plant capacity.

This would provide one desirable limitation in the operation of the program of grants and, also, it would operate to insure that the plant would be run with a high load factor once built. Some mechanism might be considered for paying a portion of the extra costs during the initial high cost and largely experimental operations.

There probably should also be a limitation that a grant could not be more than something up to 50 percent of the total estimated capital

cost of the nuclear powerplant. It is recognized that there are many inherent problems in arriving at the mechanics, making these determinations, and agreeing on the figures but it seems to us that these could be worked out satisfactorily under these general principles. Research and development assistance should also be available under the program.

A simple case might serve to illustrate the suggestion. Let us assume a conventional powerplant with a capital cost of $150 per kilowatt, 14 percent annual fixed charges, and 80 percent plant utilization factor. The capital charges for the conventional plant would then be 3 mills per kilowatt-hour.

It will be assumed that the operating and maintenance costs will be 0.5 mill per kilowatt-hour and that the fuel cost will be 4 mills per kilowatt-hour. The total power cost would then be 7.5 mills per kilowatt-hour.

The proposed nuclear plant will be assumed to have an operating and maintenance cost of 0.5 mill per kilowatt-hour and a nuclear fuel cost of 3 mills per kilowatt-hour, 1 mill per kilowatt-hour less than for the conventional plant.

The capital charges for the nuclear plant then can be 4 mills per kilowatt-hour to equal the conventional plant power cost of 7.5 mills per kilowatt-hour. At 14 percent annual fixed charges and 80 percent plant utilization factor the allowable nuclear plant cost is then $200 per kilowatt.

If the actual cost of the nuclear plant is $320 per kilowatt then the difference between the actual and the allowable cost is $120 per kilowatt. A grant of 75 percent would amount to $90 per kilowatt and the cost of the plant to the utility would then be $320 less $90 or $230 per kilowatt.

The actual power cost would be 8.1 mills per kilowatt-hour as compared with 7.5 mills per kilowatt-hour for the comparable conventional plant capacity.

After the plant is installed there would be an incentive to the utility to operate the plant to the maximum since the operating costs would be lower than for the comparable conventional plant—3 versus 4 mills per kilowatt-hour. There would be an incentive to improve operations and reduce nuclear fuel costs by at least the 0.6 mills per kilowatt-hour needed to equal the cost from the conventional plant.

Such a program would appear to provide a reasonable basis for proceeding with desirable intermediate generations of nuclear powerplants on a basis providing assistance without distorting the technology and while retaining a real incentive for continued improvement.

PROTOTYPE SIZES

We are in general agreement with the ad hoc committee report with respect to the desirable size of prototype reactors being 80 electrical megawatts or less. The desirable size of a prototype will depend on the type of reactor and the features to be explored or demonstrated and should usually fall in the range of 20 to 80 electrical megawatts, at least for most prototypes of a particular concept.

Such reactors should produce power and be operated as a part of a utility system to be effective as prototypes. It seems important to us

that prototypes should be large enough so that the anticipated operating costs including nuclear fuel costs have a reasonable expectation of being brought down to the level of operating costs for conventional plants on the same system.

The prototypes will then be economic to operate as power producers over a long period on the utility system.

In some cases there may develop a necessity to build a larger semi-commercial unit for some types of reactors as a stage to bridge the gap between the prototypes and the very large reactors which may be economic earliest.

CONCLUSION

In conclusion, we would like to express our belief in the necessity for a clearly stated philosophy and overall program for the development of the peaceful uses of nuclear energy which is subscribed to by the Congress, the Atomic Energy Commission, and industry.

Such a program should be flexible and subject to periodic review but it should be based on sound principles in such a way as to provide a stable framework for the development of the nuclear power industry in the United States.

Chairman ANDERSON. Mr. Hosmer.

Representative HOSMER. Mr. Davis, you spoke on page 4 of an approach to developmental types which for the very near future would pick up and improve efficiencies and economies of certain more or less accepted types of reactors now and then of a longer range program on other types. I wonder what you had in mind as to the types that we should concentrate for such an immediate program.

Mr. DAVIS. In my opinion, the types that should be concentrated on would be the water-cooled reactors, either pressurized or boiling, the organic-cooled reactors, and the gas-cooled reactors.

Representative HOSMER. That is three.

Mr. DAVIS. Three or four, depending on how you count them.

Representative HOSMER. What phases or parts of these reactors should take the concentrated effort?

Mr. DAVIS. Probably the most important aspect at the moment which is receiving increased emphasis is the fuel cycle. It is clearly necessary to have cheap fuel if these reactors are to be successful. However, it is also necessary to have low capital costs. In this connection, I might remark that about two-thirds of the cost of a nuclear powerplant is in the more or less conventional aspects of it and only about one-third in the nuclear package. So that the problem is not only to get the cost of the nuclear package down but to get the cost of the entire plant down. A great deal of work needs to be done on both aspects of this.

Representative HOSMER. Thank you. I just wanted to fill in a little detail on your blueprint.

Chairman ANDERSON. Are there any more questions?

In answer to this question a moment ago when you mentioned these types, did you include the gas cooled?

Mr. DAVIS. Yes, I did.

Chairman ANDERSON. Do you remember the speech you made in 1957 on October 30, when the Joint Committee was encouraging greater effort in the gas-cooled reactor field?

Mr. DAVIS. Not specifically, sir, but I guess you have got it there.

Chairman ANDERSON (reading):

Next when you examine the prediction that sound decisions can be made in 1963 or 1964 to build nuclear powerplants on a substantial scale which can confidently be expected to be economically competitive in the United States I think that we must conclude that such power reactors must be of the water class.

Do you recall that?

Mr. DAVIS. I certainly do, sir.

Chairman ANDERSON. You went right along and completely excluded gas cooled. Do you still feel that way?

Mr. DAVIS. I think the gas-cooled reactors may be perhaps something a year or two behind the water-cooled reactors. I forget what dates I quoted, whether it was 1963 or 1964.

Chairman ANDERSON. You said not all of these reactors will turn out to be equally advantageous, of course, but it seems clear if any reactors are going to be in position to be exploited commercially by 1963 or 1964 they must come from among these types—the water types.

Mr. DAVIS. I would now say that I believe by this time we should have, if these gas-cooled projects go ahead, a very good basis for making a similar kind of decision with the enriched compact gas-cooled reactors.

Chairman ANDERSON. How do you feel about capacity? Are we making headway, do you think, on what we ought to have in the way of kilowatts, disregarding this talk about a kilowatt race? Do you think we are coming along in this country satisfactorily on development of reactors so that our capacity is going to be large and satisfactory by 1960, for example?

Mr. DAVIS. I believe that with the number of new prototype reactors that seem to be coming along each year there is a sufficient volume of them at least so far to provide the kind of technical data that is needed.

It is hard to say what is going to happen next year or the year after. I think to date it is certainly very nearly satisfactory.

Chairman ANDERSON. Mr. Davis, as you were leaving your office on July 3, 1958, you sent a memorandum to the Commission. I don't know what time you left the office, but not long after.

Mr. DAVIS. July 31, sir.

Chairman ANDERSON. The subject was "Civilian Power Reactor Program." I am sure you recall that. You spoke about the Joint Committee's attitude on nuclear power. You said that the Joint Committee "is adopting a view that the achievement of economic nuclear power is still a long way off, that it is therefore premature to encourage large-scale industrial participation in the United States and that as a consequence it is necessary and acceptable for the Government to engage in the construction and operation of a substantial number of large- and medium-size power reactors."

Your memorandum goes on to say "While I have generally been conservative in my views on this subject, I believe the JCAE view is too pessimistic and would like to restate my convictions about the future, a future which can be seriously affected by the matters here under discussion."

Would you feel that there is opportunity to construct these large-type reactors now and put them in operation?

Mr. DAVIS. I am sorry, Senator.

Chairman ANDERSON. You said we were pessimistic that companies were going to develop large-scale reactors right away. Do you still think we are pessimistic?

Mr. DAVIS. I believe that I was referring to the time scales which were set forth which I have already said are in our opinion somewhat conservative. My point here is that I think that when we reach a point where it can be expected that a large powerplant, if it is built, will be economic over its useful life, even though it might not be for the first 2 or 3 or 4 years of operation. I think the utilities will at that point begin to build such plants.

Some of them will build them as soon as they get this confidence. Others will wait until they get something more like a demonstration. But the shift to building what might be called commercial nuclear powerplants I think is going to largely occur in this time period between the time that there is a reasonable basis for having this confidence and the time when there is a more or less absolute demonstration that such confidence would be justified in terms of actual operating plants.

Chairman ANDERSON. Of course, members of the Joint Committee and for some time a slight majority of the Joint Committee in Congress thought we ought to speed up the program a little bit. I would like now if I might to refer to a speech you made April 1, 1955, in Chicago. You were discussing the capacities that might be developed and you say:

> On these assumptions we should have about 2 million kilowatts of nuclear power capacity in service by the end of 1960.

How do you feel about it now?

Mr. DAVIS. I think that was overly optimistic.

Chairman ANDERSON. But you said we were too pessimistic in this final message that you left with the Joint Committee. You were conservative, you said, and generally have been conservative. Do you think that 2 million was conservative?

Mr. DAVIS. Senator, I would refer you to a speech which Mr. Roddis and I gave, where we revised the figures. The revised figures you may think are still higher than may be likely. I think we tried to emphasize that these were projections basically of a long-term nature. In fact, the 2 million that came off that was simply off a rather smooth curve.

Chairman ANDERSON. You hoped there might be 5 million kilowatts by the end of 1965? Would you feel that was a justifiable hope?

Mr. DAVIS. Yes, I think it is high but I think there will be a substantial capacity by 1965.

Chairman ANDERSON. Five million kilowatts by 1965.

Mr. DAVIS. I think there might be two or three.

Chairman ANDERSON. Even that might be optimistic. I am only concerned with the fact that steadily a good deal of industry and generally speaking the Atomic Energy Commission has felt that members of the Joint Committee have tried to push too hard for a program, and it has been statements like these that have influenced people to hold back and say things are all right, they are going to have 2 million by 1960 and 5 million by 1965.

Mr. DAVIS. Senator, if I could explain a bit, I believe the talk you referred to is one in which I tried to present almost exactly the same

philosophy I tried to express here, which was that there would be a certain point in the development where utilities would start to build nuclear powerplants.

There would be another point where the bulk of them would start to because there was now a demonstration. I think if you look at that paper you will see there are some curves in there which reflect this. I think we pointed out fairly carefully that the time scale on which this was based was in fact dependent upon the success with the developments of the reactors in question, and there might be a variation by several years either way in this particular time scale. I don't have a copy with me and I have not looked at it for a long time.

Chairman ANDERSON. I would be happy to have you examine it. Let us take the United Kingdom. Let us take the Roddis speech, paper prepared jointly by Mr. Davis and Mr. Roddis on March 14, 1957.

We have estimated a total installed nuclear capacity at the end of 1964 of about 2½ million kilowatts.

Do you think that is attainable by 1964?

Mr. DAVIS. I have not tried to make any new projections, Senator. I don't believe it is impossible at all.

Mr. HOLIFIELD. Will the Senator yield at that point?

Chairman ANDERSON. Yes.

Mr. HOLIFIELD. In your answers, of course, we would be interested to know whether you predicate your answer and your estimate as to future achievement on the basis of private industry operation alone or upon the basis of the Government now stepping in and paying for up to 50 percent of the capital investment, which is only 50 percent socialism. It would be 100 percent if you build Shippingport and sell the steam to Duquesne, at 8 mills, but it is only 50 percent if you step in and pay for the capital investment, the mortar and brick, and give it to the Philadelphia Electric group or some other group, on a 50 percent socialistic basis. I would like to know in your estimates for the future if you are putting it on the basis of private investment or plus 50 percent socialistic Government money.

Mr. DAVIS. I don't think I have ever mentioned the word socialism in connection with any of my statements on the subject. I think very seriously the time scale here is dependent basically on what can be done with the development of the technology which to me means basically the reactor experiments and what have come to be called the prototypes which there seems to be debate about.

Representative HOLIFIELD. It is dependent on the Government stepping in and putting half the money into it, plus the research and development, plus free water, plus free fuel. It is dependent on all of those things. Let us look at it realistically a little bit.

Mr. DAVIS. Let us look at it this way: It is dependent upon the development and existence of some of these machines. The exact way in which they get built is one thing, but the fact is that the development does necessitate the expenditure of funds to develop fuel elements, to develop the reactors, and to have experimental reactors and prototypes.

Representative HOLIFIELD. That is right. No one will quarrel with you that when you reach the point of economic conventional competition that private industry will build by itself. This is entirely under-

standable. We have been interested on this committee for many years in getting to that point and getting to it as quickly as possible. We have had trouble, as you know.

Mr. DAVIS. Yes; I have heard so.

Chairman ANDERSON. If I may step in for a minute, the United Kingdom has announced a tentative program for the development and construction of nuclear powerplants over the next decade. The British hope to have 1.5 million to 2 million kilowatts of nuclear power generative capacity in use by 1965. If developments in this country go as I have estimated, the United States will have two and a half to three times as much capacity in operation by 1965.

That, of course, was to reassure the public that we were doing well in this country. Do you still believe we will have two and a half to three times as much as the British in 1965.

Mr. DAVIS. No; as I said earlier, it will be more likely something like 2 million to 3 million, which will be about the same as the British will have then.

Chairman ANDERSON. Will they have about two and a half times ours instead of we having about two and a half times theirs?

Mr. DAVIS. I don't believe so.

Chairman ANDERSON. The Holyoke people were mentioned in here this morning. The Holyoke plant was turned down. You had something to do with that rejection. Would you tell us why the Holyoke plant was rejected, because it has a bearing on the matter that is coming before the committee now.

Mr. DAVIS. My recollection is that at that time—the proposal was received, I guess, 3 years ago now—that we felt, the technical experts in the Commission, that it was too advanced a project to go ahead on the time scale which was proposed.

Chairman ANDERSON. Your testimony was on page 354. I will just read you one of the things. This is the 1957 section 202 hearings:

> One of the problems is that we do not know whether we can build fuel elements that will contain the fission product. At these high temperatures they are probably going to leak out of the fuel element regardless of what we do. One then has gas which is quite highly radioactive.

Aren't we coming to a similar situation with reference to the Philadelphia Electric proposal. Have we any experiments to indicate that at these high temperatures the gas can be contained?

Mr. DAVIS. In the reactor proposed by General Atomic there is provision made for actually sweeping out and removing the fission products that may escape through the inner cladding. The approach there is to acknowledge that there will be some leakage and then to take care of it.

Chairman ANDERSON. The Holyoke people this morning—I may be incorrect—testified that their approach was a little more conservative than that of General Dynamics. If theirs is more conservative and you thought theirs was too dangerous to build, where are we on this business of jumping over a whole generation? We have always proceeded by building some sort of prototype and by running hot critical and see how we came along.

Mr. DAVIS. I have to emphasize that this was 3 years ago which was more than half the time we have had a development program.

Chairman ANDERSON. This is December of 1957?

Mr. DAVIS. I think this is by way of explanation as to why we had turned it down. I believe the decision was made actually somewhat earlier than that. The proposals originally came in, I think, April 1, 1956.

Chairman ANDERSON. It was a public power project, however?

Mr. DAVIS. It was municipal; yes.

Chairman ANDERSON. You said it looks like a long-term proposition and a difficult one; one on which we have some work underway, but we feel we have to go through the exploratory stages before we can start talking about building a plant.

Yet in the Philadelphia Electric-General Dynamics we are going to jump the stages and build the plant?

Mr. DAVIS. In this particular case it has already had about 2 years of development work done prior to the time that the proposal was submitted and still a considerable period of development work remains.

Chairman ANDERSON. But no reactor has been built. The British even have not built their advanced reactor, to say nothing about their high-temperature reactor. They have done a little experimental work on the advanced but they have done nothing on the high temperature. I raise that question because you mentioned in here the fact that your company were prime contractors for engineering and construction of the proposed high-temperature gas-cooled reactor for Philadelphia Electric Co.?

Mr. DAVIS. Yes, sir. We have proposed to build it under a fixed price contract.

Chairman ANDERSON. Yes, partially; wouldn't you say?

Mr. DAVIS. I don't see anything partial about it, sir.

Chairman ANDERSON. I probably couldn't read it well. I read it as best I could. How much is the amount of money that General Dynamics is putting into this? How is it limited? A portion of it is fixed price. Bechtel's part is fixed price.

Mr. DAVIS. I was speaking only of our contract to build the reactor, in which we have contracted to build this particular reactor for $24.5 million. We will buy some of that equipment again at a price—the nuclear package—from General Atomics.

Very frankly, when I first got into this I was somewhat concerned about this. I made a review of the project and our final decision was that we should undertake this.

Chairman ANDERSON. I don't care to argue with you. I was only wondering if there was some reason why it was undesirable to skip all these steps that intervened when the city of Holyoke had its proposal here, but a perfectly satisfactory skip when Philadelphia Electric comes in. Nothing has been built that demonstrates that you can contain the radioactive element of these gases.

Mr. DAVIS. There certainly has not been a reactor built.

Chairman ANDERSON. Didn't we say that there had been a study of this graphite situation? Didn't Dr. DeHoffmann testify that they are trying to find graphite that was impermeable?

Mr. DAVIS. Yes. Various companies who are doing development work on graphite, including some of the British companies, have in the last year or so found that they are now able to make very highly impermeable or impervious graphite. This is something that simply was not available or even considered necessarily to be possible several

years ago. The point I am trying to make in connection with the Holyoke thing is that this whole technology has been developing very rapidly.

I know my views today are not what they were 2 or 3 or 4 or 5 years ago. After all, the civilian program really got started 5 years ago. We are talking about a proposal that was submitted 3 of those 5 years ago. My ideas have changed since then. I think a lot of people's ideas have changed since then.

Chairman ANDERSON. Was it any chance the Joint Committee right then in its estimate would be a little slower than you thought? Were we a little too pessimistic, or has the development been about as we predicted or even slower than that?

Mr. DAVIS. I think the technical development has been quite rapid.

Chairman ANDERSON. We are not talking about technical development nor were we at that time. We were talking about what sort of capacity we were going to have in the plants in the United States. I sat there long hours and if you remember many days all alone and heard testimony of everybody who came in, and they said that the Joint Committee was pessimistic. Everything was fine. You remember Mr. Oakes from Pennsylvania Power & Light said we don't want any money. He was back a few years later and asked for $7.5 million. Finally he said they were going to give up the project and I commended him for doing so, because he said it was not ready to be built.

Mr. DAVIS. This only illustrates the folly, Senator, of making these projections.

Mr. HOLIFIELD. Of making a speech?

Mr. DAVIS. Of making a speech.

Chairman ANDERSON. There is an old saying that a Congressman never was defeated by a speech that he didn't make.

Mr. DAVIS. I would like to stress again that the particular projection you refer to was the one that was intended to illustrate the effect of the development and not to establish a firm projection of what capacity would be in the future. It was intended to be illustrative.

Chairman ANDERSON. Do you have access to Pluto and Rover information?

Mr. DAVIS. At the present time, no, sir; I do not.

Chairman ANDERSON. Did you in the past?

Mr. DAVIS. I have had in the past.

Chairman ANDERSON. I think that is all.

Representative HOSMER. Mr. Chairman, if I may ask a question: I am a little confused by the line of inquiry here. I would like to know, is there any particular virtue in electric kilowatts that come out of a nuclear plant over those that come out of a conventional plant, or are they the same? Will one shock you more?

Mr. DAVIS. I don't think any one has ever been able to detect any difference.

Representative HOSMER. Then the real difference is in their cost?

Mr. DAVIS. This is the basic difference, and also to people who are interested in the generation of electricity, they are interested in how sure they are going to be to get the kilowatts when they need them.

Representative HOSMER. It is not unfair to try to compart progress from many kilowatts of nuclear electricity vis-a-vis conventional a country is making.

Mr. DAVIS. I don't think it demonstrates anything very basic about the technology that is in hand.

Representative HOSMER. Is it not a matter of whichever can produce the cheapest?

Mr. DAVIS. This in the end is going to be the determining factor.

Representative HOSMER. In some places the cost is more than others to produce.

Mr. DAVIS. Yes.

Representative HOSMER. A kilowatt of electricity, is that right?

Mr. DAVIS. There are wide variations all over the world.

Representative HOSMER. From an economic standpoint whether you produce with nuclear power or with conventional power you would want to produce them whichever is the cheapest, is that right?

Mr. DAVIS. You certainly want to do it by whichever is cheapest. Here I must point out that when you are talking about building a nuclear powerplant or a conventional powerplant you are interested in which is going to be the cheapest over 25 or 30 or 40 years and not which is necessarily going to be the cheapest the day you turn it on.

Representative HOSMER. You have an obsolescence problem. Actually from a plant standpoint, whether conventional or nuclear, a large investment in a plant that may become obsolete will run your cost up.

Mr. DAVIS. I don't think it is quite so much a question of obsolescence as it is that an electric generating plant simply has to run economically over its whole lifetime or it will never pay back its capital investment. The utility people by the very nature have to look ahead 25, 30, 40 years in trying to make decisions. They cannot make them on the basis of what is going to happen next year or the next year thereafter.

Representative HOSMER. You use as the yardstick the projection of your conventional costs to determine what your costs economically will be in other types of production?

Mr. DAVIS. What you certainly ought to do is to make reasonable projections of conventional fuel costs, which of course is very difficult to do, and the comparable projection of what nuclear costs may be.

Representative HOSMER. Thank you.

Chairman ANDERSON. I just want to read you the last paragraph of your memorandum:

> While the JCAE professes a desire to keep public verus private power issues out of the reactor program, it appears to me the program they are now advocating does exactly the opposite and in fact provides very great support for public power under conditions detrimental to the technical development of economic nuclear power.

We tried not to make it good that way. If there is no objection, I will put this memorandum in the record at this point because I quoted from part of it.

(The memorandum referred to follows:)

SUBJECT: CIVILIAN POWER REACTOR PROGRAM

The impending situation with respect to prototype nuclear power reactors as expressed in the current JCAE draft of the "Expanded Civilian Nuclear Power Program" in H.R. 13121 and S. 4051 reported out by the JCAE on July 3, 1958, and the accompanying report gives me extreme concern. The philosophy represented in those documents is not only contrary to the views previously expressed by the Commission and the administration but can be highly detrimental to the

development of nuclear power and the establishment of a nuclear power industry in the United States. I wish to record my views on this subject and to urge as strongly as I can that the Commission take a strong and positive position in opposition to many features embodied in the referenced documents.

If the philosophy advocated by the JCAE is adopted the Atomic Energy Commission will be obliged to designate reactors for construction (by type and size) by pressure to do so or else be accused of not prosecuting an aggressive program. The JCAE directed design studies are an additional device which will lead to still further pressure for additional reactors. Since there is, in my opinion, little likelihood of industry being able to participate under the conditions which appear likely to be specified, and no other mechanics is provided for them to participate, the inevitable result will be governmental construction of initial and intermediate stage reactors until industry is able to undertake such reactors completely on their own with no assistance of any type.

The pattern being established by the JCAE would require the AEC to establish the type and size of a reactor to be constructed (and would be limited to second and later generations) as a condition of any industrial participation. Industry would then presumably be given a short time period (60 days in the case of the gas cooled power reactor) to make definitive proposals and then the AEC and the proposers would be given a short period (90 days in the case of the GCPR) to arrive at final contract terms. The AEC would be obligated, once it had designated a reactor by type and size, to construct it as a governmental project if no proposals were received or if a contract could not be negotiated in the inadequate periods allowed. There would be no provision whatsoever for projects initiated and proposed by industrial groups except to obtain special authorization outside of any established or regular programs. The only possibility would be for the AEC to propose a particular reactor when it knew such a reactor was desired by an industrial group, and this could lead to charges of favoritism and collusion even though the JCAE suggests an "advisory" committee to recommend selections.

The industrial projects to date have developed from extensive studies over a considerable period of various reactor types for a specific application and negotiations between various manufacturers, architect-engineers, and utilities. Aside from the possibility of tailoring an invitation to fit a particular proposal known to be under consideration there is a low probability that any particular AEC invitation would fit the ideas and requirements as to type and size of a particular group or that a group could make the necessary design, cost, and evaluation studies, complete the necessary negotiations, and prepare an adequate proposal in the time available (even if it were very substantially longer than the 60 days provided for in the case of the gas cooled power reactor) even if they were interested in the type and size of reactor specified. While negotiation of contract terms with the Atomic Energy Commission might be feasible in periods of time such as the 90 days provided for the GCPR this would be made especially difficult by hasty submission of proposals. It should be emphasized that there are only a very limited number of groups at any one time interested in and capable of taking on the construction (at their own expense) of a large power reactor.

The pattern sought by the JCAE is clearly defined in the fiscal year 1959 authorization bill and report and in their version of the "expanded civilian nuclear power program." This pattern will, I believe, inevitably lead to governmental construction and operation of a substantial number of large-scale power reactors without providing a real opportunity for industrial participation which has been the keystone of the AEC philosophy—in fact, it will have the effect of substantially precluding such participation.

The JCAE is adopting a view that the achievement of economic nuclear power is still a long way off, that it is therefore premature to encourage large-scale industrial participation in the United States and that as a consequence it is necessary and acceptable for the Government to engage in the construction and operation of a substantial number of large and medium size power reactors.

While I have generally been conservative in my views on this subject, I believe that the JCAE view is too pessimistic and would like to restate my convictions about the future, a future which can be seriously affected by the matters here under discussion.

One should distinguish between the point in time representing the initiation of final design and construction of a power reactor which I have generally used as a reference point and the point where a reactor has been built and

operated at least for a short period under design conditions which is the point of "demonstration" used as a reference point by the JCAE and some others. There will be a difference of 3 or 4 years between these points in most cases.

Using my reference point of initiation of design and construction, I firmly believe that such a point will be reached where reactors can be started which can confidently be believed to be economic over their useful lifetime in 2 or 3 years in several areas abroad, and 4 or 5 years in several areas of the United States. Such reactors would then be in "normal operation" by 1964 or 1965 abroad and by 1966 or 1967 in this country. It is my considered judgment that these are still sound and conservative estimates and that a few isolated cases of economic use may be found both abroad and in this country a year or two sooner. On the other hand, the areas where nuclear power reactors will be economic by the times predicted will be limited to those of relatively high fuel cost and to those where very large power units (150 to 300 EMW and larger) are needed and can be accepted in the distribution systems. It is further my belief that the reactors which will accomplish the above at the times specified will most likely be water cooled with the organic and gas cooled reactors being real additional possibilities.

As you know, I have advocated the following principal steps toward a sounder and more aggressive civilian power reactor program during the past year (and most items even earlier):

(*a*) A more flexible approach to the scope of the R. & D. support and conditions of the power demonstration reactor program, both for reactors identified as desirable by the AEC and for reactors initiated by industry.

(*b*) That the AEC, at least in some cases, go one step beyond the "reactor experiment" and build what I have called "experimental reactors" of a somewhat larger size.

(*c*) That the AEC propose authority to establish a program of grants to cover a limited portion of the difference between the cost of prototype nuclear powerplants and conventional powerplants. I have proposed that this be done, only after design studies and competitive proposals for specific plants believed to be timely and desirable by the AEC.

I still believe that these are essential steps in a sound and aggressive program along with the basic research and development program, and the reactor experiment projects, the applied fuel cycle program, and the Euratom program. It is essential that a mechanism be continued for cooperative development on projects initiated by industry under the power demonstration reactor program.

While I believe that the National Laboratories and major AEC research and development contractors are invaluable in the basic research and development program, and the development, design, construction and operation of reactor experiments, I feel it is essential that the design and construction of experimental reactors along with related development be carried out by contractors (engineers and manufacturers) who can reasonably be expected to engage in the commercial applications of such reactors. I believe it is very necessary that any later generation plants be built with the maximum amount of industrial participation and responsibility if these plants are to make the necessary contributions toward achieving economic nuclear power. The construction of such plants under governmental responsibility is not likely to accomplish this.

While the JCAE professes a desire to keep public versus private power issues out of the reactor program, it appears to me that the program they are now advocating does exactly the opposite and, in fact, provides very great support for public power and under conditions detrimental to the technical development of economic nuclear power.

W. KENNETH DAVIS,
Director, Division of Reactor Development.

Chairman ANDERSON. Thank you very much for being here. Some of us think you were more optimistic and whether we were pessimistic we are glad to have you with us.

Mr. DAVIS. Thank you very much, Senator.

Chairman ANDERSON. The last witness is Mr. McDonald.

STATEMENT OF ANGUS McDONALD, COORDINATOR, DIVISION OF LEGISLATIVE SERVICES OF THE NATIONAL FARMERS UNION

Mr. McDONALD. Thank you.

Chairman ANDERSON. Mr. McDonald we are glad to have you here.

Mr. McDONALD. Thank you, Mr. Chairman.

I have an extremely brief statement.

At previous hearings of this committee, we have expressed at some length the interest of the National Farmers Union in a Federal program which would call for the building of a number of large scale nuclear power reactors. We have not changed our views since we appeared here February 21, 1958, believing that changes in technology and in the world situation make more necessary than ever the inauguration of such a program which would also include the building of a number of smaller reactors of from 5,000 to 50,000 kilowatts.

While we realize that atomic development is more than a race to determine which country can manufacture the most kilowatts, we believe the number of kilowatts generated is one of the measures of progress in the atomic energy field. We are therefore in accord with the goal of 1 million kilowatts by 1965 as stated in the Gore bill (S. 863). In this connection we call attention to the progress of the British who it is said lead the world in nuclear power production.

Significant also is the progress made by other countries not the least of these being the Soviet Union. According to Dr. Walter Zinn, one of the world's great authorities of reactors, the Russians have made amazing progress in the nuclear power field both in the diversity of their experiments and in the size of their reactors. At the present time they have under construction a 400,000-kilowatt reactor, a 150,-000-kilowatt Czech reactor, and a 100,000-kilowatt Siberian reactor already completed, as well as a number of smaller ones being built or already in operation.

We are very much impressed with the Zinn report (see p. 48) and as well as the recent report of a British scientist, Sir. John Cockroft, who said of the Russians:

> They are faced with the same problems but they work three or four times faster. I think they will leave us behind in the future.

According to the December 11, 1958, Atomic Power Newsletter of the American Public Power Association, Nikolai Tarasov, a Soviet official of the Ministry of Electric Stations, stated that the Russians had two 420-000-kilowatt reactors and one of 400,000-kilowatt capacity under construction.

It has been alleged that our atomic electric power program has been lagging because the private utilities either could not or would not go ahead but were successful in blocking any substantial Federal power program. The issue of public versus private power has unfortunately been injected into the consideration of future nuclear power development. We feel that the real issue is whether or not the United States should go full steam ahead with a nuclear power program.

While we believe that nuclear fission is a public resource which has been developed with taxpayers' money and that the yardstick principle and the preference clause should be applied to Federal genera-

tion and distribution of electric energy produced by means of atomic energy. We also believe that there is plenty of room for a Federal program, a municipal and cooperative program and a so-called private utility program.

We agree with the statement of the ad hoc committee on reactor programs and policy of the Atomic Energy Commission:

> For us to fall behind in developing the civilian use of energy from nuclear fission would raise doubts as to our interest in peaceful applications of this great discovery or as to our technological competence.

Chairman ANDERSON. Let me say that when a man is allowed a half hour and confines his statement to a page and a half at this hour of the day, he has our thanks.

Mr. MCDONALD. Thank you.

Chairman ANDERSON. If there are no questions from the committee, thank you very much for a very fine statement.

(Whereupon, at 4:20 p.m., Thursday, February 19, 1959, the committee was recessed until Tuesday, February 24, 1959, at 10 a.m.)

DEVELOPMENT, GROWTH, AND STATE OF THE ATOMIC ENERGY INDUSTRY

TUESDAY, FEBRUARY 24, 1959

CONGRESS OF THE UNITED STATES
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C.

The committee met, pursuant to recess, at 2 p.m., in room P–63, the Capitol, Representative Chet Holifield, presiding.

Present: Senators Anderson (chairman) and Dworshak; Representatives Holifield (presiding), Durham, Van Zandt, Hosmer, Aspinall, Bates, and Westland.

Also present: James T. Ramey, executive director; John T. Conway, assistant staff director; David R. Toll, staff counsel; George F. Murphy, Jr., professional staff member; Edward J. Bauser, technical adviser, Joint Committee on Atomic Energy.

Representative HOLIFIELD. The committee will be in order. In view of the fact that some of the members are being detained today because of a special meeting with some of the people from Euratom, I have been asked to chair the committee and proceed with the hearings on schedule.

At this time we will ask John N. Keen of the Wolverine Electric Cooperative, Big Rapids, Mich., to come to the witness chair.

STATEMENT OF JOHN N. KEEN, MANAGER, WOLVERINE ELECTRIC COOPERATIVE, BIG RAPIDS, MICH.

Mr. KEEN. Thank you, Mr. Chairman.

Representative HOLIFIELD. Mr. Keen, do you have a statement for the committee?

Mr. KEEN. Yes, I have, Mr. Chairman.

Representative HOLIFIELD. You may proceed.

Mr. KEEN. Mr. Chairman and gentlemen, I am John N. Keen, manager of Wolverine Electric Cooperative, Inc., of Big Rapids, Mich.

It is indeed a pleasure to again appear before you and your committee in order that I might inform you of Wolverine's continued interest in the civilian application of the nuclear power reactor program.

We highly commend the splendid work submitted by the ad hoc committee in their report of January 2, 1959, particularly where they recommend methods of Government assistance in implementing the program with a view to maximum flexibility and minimum distortion of the technology, and wherein they recommend that prototype reactors should be emphasized rather than larger power reactors until the latter can be wholly or nearly self-supporting. This gives us en-

couragement to proceed with our endeavors to assist in the development of economical nuclear power as rapidly as possible.

We believe more effort should be applied and consideration given to the smaller prototype plants with a net electrical output of 5 to 50 megawatts until such time that we are confident of reaching a competitive position with fossil-fueled plants. Our basic reasons for this are as follows: (*a*) The construction of smaller plants is less costly; (*b*) operating costs are less which results in less money needed to carry out this development; (*c*) there is a definite need for smaller type plants for the smaller utilities, municipalities, rural electrification cooperatives and many of our friendly foreign countries, many of whom are burdened with excessively high fuel costs.

On February 1, 1956, Wolverine Electric Cooperative submitted a proposal to the Atomic Energy Commission for the construction and operation of a 10-megawatt aqueous homogeneous reactor to be installed on Wolverine's property, located in Hersey, Mich. This proposal was submitted under the second round of the Commission's demonstration reactor program. Our proposal was accepted by the Atomic Energy Commission in principle, conferences were held to inspect the proposed site and to negotiate proper contract language. These conferences continued until August of 1957, at which time the reactor manufacturing company (Foster Wheeler Corp.) informed Wolverine that due to rising costs and uncertainties that had arisen in regard to homogeneous concepts, they were compelled to withdraw their firm quotation and could only undertake their portion of the contract on a cost basis.

On May 13, 1958, Wolverine Electric Cooperative was informed by the Atomic Energy Commission that for the best interest of both the Government and Wolverine, that the present Wolverine project be dropped. However, hope was expressed that Wolverine would continue to explore other possibilities in the atomic energy field.

Since that time Wolverine has continued to explore reactor concepts with other manufacturers, and approximately 1 year ago we became interested in the outstanding progress being made by the EBWR. As a result, we exerted our efforts in exploring this type of reactor. We have continued to keep ourselves informed on other types of reactors as well. During the last few months, we have been actively working with the American Standard Co. on their concept of the variable moderated reactor. We feel that this concept has great possibilities of developing into a reactor that will be competitive to fossil-fueled plants in certain parts of the United States in the not too distant future. However, we feel that additional development work must be accomplished and operating experience gained in order to reach this goal. A prototype reactor of this concept will have many advantages in bringing competitive nuclear power to the general public at an early date at considerably less cost, not only to utilities that are willing to assist in this program, but to manufacturers, and the Government as well. In general, we feel that the Government's plans for the domestic application are sound and with continued efforts of utilities, manufacturing companies, and the Government's continued cooperation and support of all concerned, our goal may be reached at an early date.

Wolverine's interest in nuclear power stems from the fact that we are in one of the higher fuel cost areas of the United States and as we look to the future we believe it is imperative that we again offer the facilities of our utility to assist in the development of economical nuclear power. In this respect our position is excellent, both with respect to site and because of our interconnections with small municipalities and other utilities with a resulting flexible load pattern that will be very adaptable to the size and type of reactor we plan to propose.

In conclusion, May I state that after 4 years of working with the Commission in its efforts to develop economical nuclear power, I am convinced that the greatest economies will accrue through a reduction in the capital costs of the reactor plant and in a lowering of the manufacturing and processing costs relating to the fuel cycle. In both of these areas cost reductions of major significance will only occur as the result of standardization and quantity production. A broad policy leading to the early construction of many plants should be less costly to the Government in the long run than the continued custom construction of "one shot" plants. Furthermore, the development of the broad base of manufacturing and operating personnel who would be associated with the construction and operation of many plants would inevitably lead to earlier development of those improvements which can only come as the result of experience.

Representative HOLIFIELD. Thank you, Mr. Keen. Mr. Van Zandt?

Representative VAN ZANDT. I have no questions.

Representative HOLIFIELD. Mr. Hosmer.

Representative HOSMER. No questions, Mr. Chairman.

Representative HOLIFIELD. Mr. Bates.

Representative BATES. Mr. Keen, it is your judgment that we should dedicate ourselves to prototypes in the field of 5 to 15 megawatts until such time as they are competitive with conventional fuels?

Mr. KEEN. Until they are competitive or nearing competitive fuel.

Representative BATES. You feel it is a waste of money and waste of talent if we were to project ourselves into large-scale commercial plants until such time as they are competitive or near competitive?

Mr. KEEN. The first part of your question on the waste of money, it would be very probable. The waste of talent, no. The improvements coming out of whether it is a small prototype plant or large plant I believe would be equal. However, it would be more costly, particularly from the operating standpoint for a large plant than it is for a small prototype.

Representative BATES. You feel we can learn as much with a 15-megawatt reactor as we could with one much larger.

Mr. KEEN. In many, many cases, and in practically all cases, yes.

Representative BATES. I have no further questions.

Representative HOLIFIELD. Mr. Aspinall.

Representative ASPINALL. There is a place, though, Mr. Keen, is there not, where you go through research work and you don't get answers that go with larger operations? Do you wish to wait in this program until we come to a competitive place before we throw any money into a large plant to see what we can do with it? Is that your position, as I understand it?

Mr. KEEN. No, not quite. They can go concurrently. However, the most promising developments can be carried out in a prototype

plant, just as easily and with less expense than in a large plant and the same results would be gained. However, in the test-tube type, I presume you are referring perhaps to hot loops or something of that nature?

Representative ASPINALL. I am just referring to small operations. It seems to me that at the present time there is a tendency to say, all right, we will take care of test-tube operations. I don't care whether it is in the atomic energy program or where it is. But when it comes to pilot or demonstration plants, where you really find the answers to the problems that are involved on a competitive base, we shy away from those. I think someplace along the line we have to get away from that philosophy and get out in front where we can find some answers. As I understand you, you state that you can find the answers in the small prototype plant that you can find in a large operation, to a great degree. That is not the history of research.

Mr. KEEN. When I say small plants, I am talking about 5- to 50-megawatt plants. I believe it would produce as much information as a 100-megawatt and 200-megawatt plant, as far as information is concerned.

Representative ASPINALL. I think we should be very sure that is exactly what we will find. I am not so sure that the history of research in anything proves that point.

Representative HOLIFIELD. Mr. Westland.

Representative WESTLAND. Mr. Keen, I am not familiar with the Wolverine Electric Cooperative. Would you tell me a little bit about it? The size, the kilowatts a year that you sell to customers?

Mr. KEEN. Yes. We serve about 22,000 rural customers indirectly. We are a generation and transmission cooperative, wholesaling power to other distribution cooperatives, municipalities. We have a physical tie with our public utility which is the Consumers Power Co. in Michigan in our area. The ones that are served directly by our members, it amounts to about 22,000 rural homes. Our annual sales are approximately 100 million kilowatt-hours.

Representative WESTLAND. You say you generate power?

Mr. KEEN. We generate most all of our power, although we do have interconnections with municipalities and also with the local utility in our area. We generate about 85 percent of our own power.

Representative WESTLAND. Is it steam?

Mr. KEEN. No; all of ours fortunately so far is internal combustion. We have been able to capture some rather economical natural gas that is produced in Michigan. Due to the thermal efficiency of internal-combustion gas, diesels are able to utilize the natural gas. In the future we have to look farther for additional sources of power.

Representative WESTLAND. What do you figure your cost of producing power?

Mr. KEEN. On the board our cost is approximately 8 to 9 mills.

Representative WESTLAND. The first project you were interested in was an aqueous homogeneous project. Would that be competitive?

Mr. KEEN. We did not consider when we submitted our original proposal on the aqueous homogeneous reactor that it would be competitive at that time with current fuel costs. However, as will be poined out to you in the next testimony, the advancements that have been made in the boiling water reactor, and the concept that we are

now working with shows a great deal of promise of being competitive or approaching very, very closely to competition.

Representative WESTLAND. Were you in agreement with the AEC that this aqueous homogeneous reactor should be dropped? Was the Wolverine Electric Cooperative in agreement?

Mr. KEEN. We agreed with it; yes.

Representative WESTLAND. You sort of smiled when you said that, Mr. Keen. Did you really agree?

Mr. KEEN. Frankly, it is a rather difficult question for a person such as myself to answer. I do feel this way, that eventually the aqueous homogeneous reactor concept is going to have to be worked out. The problems are going to have to be solved. Whether it is going to be less costly to solve them in the future or if we should go to work on it immediately, I would not attempt to answer. But it will have to be done some time.

Representative WESTLAND. What was your contribution expected to be to the development of that reactor?

Mr. KEEN. We were contributing the site, and were willing to pay for steam at our fuel cost or what it cost us to produce power from other means in Michigan. Due to the fact that we are in a high-cost area, and with the same ground rules, it would be a substantially larger contribution than if you were in a low fuel cost area.

Representative WESTLAND. This was a proposition where the AEC would build the plant and you would buy steam from them at somewhere between 8 and 10 mills; is that right?

Mr. KEEN. That is approximately right.

Representative WESTLAND. You would enter a contract for a certain number of years at that price?

Mr. KEEN. That is right. With Wolverine's option to purchase the Government's interest at the end of that period.

Representative WESTLAND. Do you feel that these reactors can fit into your project and into your business and do you feel that the AEC should perhaps establish by the construction of these prototypes the fact that power can be produced at 8 to 10 mills before you build one yourself or enter into a contract with AEC.

Mr. KEEN. That is the only way that I can see that this program can be carried out with small utilities, the municipalities and rural electrification cooperatives until such time as it does become competitive where we can than stand on our own feet and take care of everything entirely ourselves.

Representative WESTLAND. In other words, your company is not financially capable of building a reactor at 12- or 14-mill cost and put it into your lines and absorb the excess cost?

Mr. KEEN. That is true, because the REA Act definitely states that it is our duty to furnish the rural areas with the most economical power that we can acquire. Of course, that does not mean just today, but in the future as well. That is one reason why we are very interested in the nuclear program. Due to the fact that our fossil fuels are receding, particularly in Michigan where we are on a peninsula, and we have transportation problems, we see freight increases to haul our fuels into Michigan, and I see no letup of that, I feel very strongly that we have to fortify ourselves and look to something else in the future.

Representative WESTLAND. I believe P.G. & E. is planning to build a reactor at Humboldt, which they feel will be competitive at around 2 to 10 mills. Are you familiar with that?

Mr. KEEN. Slightly.

Representative WESTLAND. Does your company keep in touch with those sorts of things?

Mr. KEEN. We keep in contact with all the release concepts that are being worked on. We keep up to date on them quite readily. We work very closely with the people down at Detroit on the Enrico Fermi plant.

Representative WESTLAND. That is all.

Representative HOLIFIELD. Mr. Keen, under the 1956 act, you did have a proposal before the Atomic Energy Commission, as you said, for the construction of 10 megawatt aqueous homogenous reactor. Some 2½ to 3 years later this was abandoned because, as I remember, the firm contract price has gone about from $4 million to about $14 million; is that not right?

Mr. KEEN. That is right, sir.

Representative HOLIFIELD. That proposal and your interest in it stem from the fact that you were operating under the so-called second-round proposal of the Commission.

Mr. KEEN. That is right, Mr. Chairman.

Representative HOLIFIELD. Under that second round the Federal Government took the responsibility for building the reactor and furnishing the electricity to the users on an agreed upon negotiated basis which they could afford to pay.

Mr. KEEN. With one correction.

Representative HOLIFIELD. To furnish the steam at a thermal kilowatt price which they could afford to pay, I should have said.

Mr. KEEN. That is right.

Representative HOLIFIELD. You are aware that the present proposal of the AEC, both in their oral presentation to us and also in the draft of the authorization bill excludes any second round proposal such as that.

Mr. KEEN. Very definitely.

Representative HOLIFIELD. You are also aware that they have proposed something which is in the nature of a grant-in-aid proposal for capital plant investment.

Mr. KEEN. Yes, sir.

Representative HOLIFIELD. Do you understand that that proposal of theirs would contribute up to 50 percent of the capital plant investment of the whole plant, nuclear reactor, generators, heat conversion, and everything up to the bus bar?

Mr. KEEN. That is my understanding; yes.

Representative HOLIFIELD. Do you understand that in addition to that 50 percent contribution which they propose they would also propose fuel for 5 years at no cost and other research and development help, and furnishing of heavy water in case it happens to be a reactor that needs heavy water for a moderator.

Mr. KEEN. That is right.

Representative HOLIFIELD. Under that proposal and considering the fact that you are working under the REA Act, could you participate in that type of proposal in view of the fact that the building of a reac-

tor of this type could not be estimated to be competitive with conventional power costs in your area?

Mr. KEEN. I would be very skeptical of it for any rural electric cooperative or for any municipalities or smaller utilities. It might be possible in some cases.

Representative HOLIFIELD. In borrowing the money to participate in this plan, you would have to go before the Government loan people and guarantee to them that the resulting kilowatts that you would get would be cheap or that they would be competitive with conventional produced kilowatts, would you not?

Mr. KEEN. Yes, sir. I believe at this time with the technology we have as of today, and with the operating experience we have on reactors, it would be very difficult to prove to the REA or to the Government.

Representative HOLIFIELD. As a matter of fact, it would be impossible to prove it.

Mr. KEEN. That is right.

Representative HOLIFIELD. The only thing you could do would be to speculate.

Mr. KEEN. That is right. However, we cannot speculate.

Representative HOLIFIELD. There have not been as yet any kilowatts produced that are economic and competitive with conventionally produced kilowatts.

Mr. KEEN. That is right. If that was the final decision the rural electrification cooperatives undoubtedly would be forced to withdraw.

Representative HOLIFIELD. If there is to be any participation in this field of development on the part of your cooperative or any other cooperatives operating under the same legal restrictions, there would have to be something like the second round reinstated.

Mr. KEEN. Something similar to that, yes, sir.

Representative HOLIFIELD. Mr. Hosmer.

Representative HOSMER. What per mill cost from a nuclear plant would you have to get for nuclear to be competitive with conventional in your area?

Mr. KEEN. Wolverine would be willing to pay for steam an equal amount that steam or power would cost from our present source. Fuel cost alone would range in the neighborhood of 4 to 5 mills. The fuel plus operating and maintenance cost—in other words, bus bar cost as we commonly term it—would be between 8 and 9 mills.

Representative HOSMER. In relation to the matter of prototype plants, is it true that the prototype plant could be constructed appreciably faster than a large plant.

Mr. KEEN. I would rather have other experts on the program answer that for you because they are the technical people and the proposed constructors of this plant we are now discussing.

Representative HOSMER. I am talking about in general.

Mr. KEEN. In general my personal opinion is this: After the engineering work is completed, as far as construction is concerned it is a matter of manpower and availability of materials regardless of the size of the plant. Perhaps one would go nearly as rapidly with one as another. However, we should be able to construct a prototype plant a few months earlier than a larger one.

Representative HOSMER. Does a prototype plant afford somewhat more flexibility in experimentation because if you shut it down, you are not shutting down such a major portion of your existing power source?

Mr. KEEN. That is one of the advantages. Another advantage is that if you determine that the fuel elements should be changed or revamped, there would be a lot less fuel involved, a lot less fuel rods to reproduce and therefore much less expensive.

Representative HOSMER. Then I would conclude that the possibility of technological advances can be obtained more cheaply using the prototype system.

Mr. KEEN. That is our feeling, also.

Representative HOSMER. In relation to the capital cost proposal made by Mr. McCone, do you understand that to include grants amounting to more than your conventional cost of a plant? I mean by that, it would actually subsidize some part of the conventional cost?

Mr. KEEN. That is not my understanding. I can see where that would be a possibility. However, on the size of plant and the type of plant that we are now working on, I believe it would be a tossup as to which is more expensive—the nuclear section or the conventional section of that plant.

Representative HOSMER. Assuming that the capital grant portion would be $10 million, for example, would that make any difference in the end whether it was called a capital grant or whether it was $10 million advanced for Research and Development work?

Mr. KEEN. If I understand your question properly, let me restate it in my language to see whether I am with you or not. You are stating this. If we were granted $10 million to build a certain plant, and it cost us $3 million to build it, the rest of the money would be Wolverine's to subsidize the operating cost or something of that nature, if we so desired?

Representative HOSMER. No. I am talking about the present system where AEC puts up $10 million in research and development money as against $10 million toward the ultimate construction price. Does it make any real difference in the end? It is still $10 million.

Mr. KEEN. It is still $10 million. But Wolverine and other cooperatives would need assurance that if the figures are wrong on the estimated operating cost, there would be a subsidy to cover the difference in operating cost until such time as the operating costs are reduced to the competitive fuel or the project is completely abandoned.

Representative HOSMER. Or as in your proposal, control by fixed cost of the steam.

Mr. KEEN. That is right.

Representative HOSMER. Thank you.

Representative HOLIFIELD. Are there any further questions of Mr. Keen? Is not, thank you, Mr. Keen.

Mr. KEEN. Thank you, Mr. Chairman and gentlemen.

Representative HOLIFIELD. We will now have Mr. J .C. Linsenmeyer of the American Radiator & Standard Sanitary Corp. for our next witness.

STATEMENT OF JOHN C. LINSENMEYER, EXECUTIVE VICE PRESIDENT, AMERICAN RADIATOR & STANDARD SANITARY CORP.

Mr. LINSENMEYER. Mr. Chairman and gentlemen, I am John C. Linsenmeyer, executive vice president of American Radiator & Standard Sanitary Corp. It is a pleasure to respond to your invitation to present our observations on the state of the atomic energy industry.

Mr. John Keen of the Wolverine Electric Cooperative, who has just testified, has mentioned our variable moderator reactor that his organization is considering. I would like to tell you briefly about this design. We started to work about 2 years ago after systematically reviewing many potential types of nuclear systems. At the same time, we were fortunately engaged in an evaluation program for the AEC to determine the influencing factors on the power costs of PWR, Calder Hall, and several other proposed nuclear plants. With this background we perhaps more than others were particularly aware of what had to be done to get economic nuclear power.

It was apparent to us at the outset that in order to get lower power costs four things must be accomplished: (1) reduce the plant capital costs; (2) improve the overall efficiency of the plant; (3) lower the fuel cycle costs; and (4) increase the specific thermal output of the reactor. Capital cost reduction seems to be the factor that could have the earliest and largest contributing influence on reducing power costs. Nuclear systems have a disproportionately high capital cost over conventional plants due primarily to requirements for precision fabrication, the special metals employed, and unusually stringent safety considerations.

Our variable moderator reactor is a boiling water reactor that is controlled by raising and lowering the level of the moderator water surrounding the fuel elements. With this type of control all mechanical devices, including the costly control rods, are completely eliminated from the core. Not only is there substantial savings by eliminating the control rods themselves, but there are other important related savings as well; for instance, when control rods are used in a reactor, the top closure must be precisely alined with the core and pressure vessel in order that the control rods penetrate the core exactly. When the rods are eliminated as in the variable moderator reactor, the reactor vessel core, core support, and other materials are fabricated using commercial tolerances, and the net result is a large capital cost saving.

While we propose a major improvement in the variable moderator reactor, we have still stayed within known and proven boiling water reactor technology. In summary we feel the boiling water reactor holds the best promise for early economic power, and the VMR as a major improvement in the boiling water reactor's design represents the surest method of attaining this goal.

Our VMR system is also designed to accommodate nuclear superheat as soon as the technology of high temperature and pressure superheated systems are developed. A superheater can be added to the variable moderator reactor by change in the core design but retaining the water moderator level control system unchanged. The addition of superheat in the VMR is relatively simple because of the absence of

complicated control mechanisms which must pass through additional tube sheets needed for superheat. This makes the variable moderator reactor unique in its ability to take advantage of future improvements when they become apparent.

Programs on improved fuel cycle costs and lengthened fuel life are supported at a number of organizations, including our own. The information gained from these investigations can be directly applied to the design of the fuel elements of the VMR as we expect to use standardized fuel elements equally adaptable to our VMR as to other boiling water reactors. We feel this standardization and interchangeability is extremely important in reducing fuel costs.

The other area of potential cost reduction is accomplished in upping the power output of reactor systems. The boiling water reactors have dramatically demonstrated this potential at Argonne National Laboratory on the EBWR. The EBWR more than tripled its power output without any increase in physical size. This in effect cuts the installed cost per kilowatt of the nuclear portion of the plant by a substantial amount, a most remarkable achievement.

Although the VMR is presently designed on the conservative basis of EBWR's original power level, we await only the acquisition of operating experience with the reactor before we can almost assuredly increase the power output of the VMR in like fashion. This would permit a utility system to add additional generating capacity as the reactor demonstrates its capability after initial operation and as the system load growth requirements demand. While we are planning to propose a demonstration project with Wolverine, we have also submitted a separate research and development proposal to the AEC under the new reactor concepts program which covers an investigation of the important VMR research problems as we see them. We understand it is under consideration.

In Chairman McCone's testimony, he described two important areas in which a lower cost boiling water reactor is urgently required—for the generation of process heat and for generation of 5 to 40 megawatts of electric power. The use of variable moderator control to eliminate control rods permits a large relative cost reduction in these smaller reactors. As I see it, the elimination of control rods is the next major step forward in reactor technology, and we stand now with respect to it about the same point as we were several years ago with respect to the boiling water reactor principle itself. At that time it was recognized that direct boiling in the reactor core was highly desirable in terms of power cost, but there was fear that the reactor would not be stable. The splendid and courageous work of Dr. Zinn and other AEC scientists demonstrated experimentally that this advance could be made, and the boiling reactor is today a main foundation of our reactor program. I suggest that the Commission and the Congress now take a similar step with respect to research work and the construction of a prototype boiling water-plant on the variable moderator principle. The probability of success is great and the rewards are rich.

In order to accomodate this and other important programs, American-Standard is presently consolidating its activities in the atomic energy field and related fields. Through this consolidation we will double our staff over the next several months at our laboratory in

Mountain View, Calif. Supported by our industrial division and Detroit controls, which have been active in the power field for many years, we are prepared and qualified to undertake this project with the Wolverine Electric Cooperative.

I would like now to comment briefly on the subject of one of the topics that you have suggested for discussion. In connection with the Government power reactor policies and programs, I would like to emphasize the importance which we attach to the desirability of constructing prototype reactors of new reactor developments. The Joint Committee in its report, the AEC's ad hoc advisory committee, and Chairman McCone in his testimony have emphasized the importance of first building small prototype power reactors before proceeding with the construction of large plants. The advantages in small prototype plants have been clearly emphasized in these reports. However, I would like to talk with you about a corollary advantage on which we feel has been placed too little emphasis.

Incidentally, gentlemen, the use of the word "prototype" may be misleading somewhat. In regard to Mr. Aspinall's comment, it is not by any means a test tube, or apparatus for laboratory experiment. It merely means a relatively small size plant. One of the advantages accruing therefrom is that a family, or sequence, of such plants can be built somewhat more quickly and certainly with a great deal less expense than a similar family or sequence of large plants.

Representative VAN ZANDT. Could we call them a first generation?

Mr. LINSENMEYER. That is right. As I think I emphasized last year before the committee here, I think progress comes from sequence or families and not from any single great stroke of genius.

Chairman ANDERSON (presiding). Which generation is it? The prototype?

Mr. LINSENMEYER. Again we will have to define generation. Wherever we start on this, with smaller plants we can expedite progress toward competitive nuclear power. Whether the particular one we are discussing now is a son or grandson, the subsequent generations can come more quickly, and more economically.

Representative HOLIFIELD. I would like to explore that a little bit further, because I think it is very important that we keep this term "prototype" clear. When I say size, I am measuring in terms of kilowatt output. The size can vary with different types of reactors. It cannot only be a first generation, but it can be a second or third generation.

Mr. LINSENMEYER. That is right.

Representative HOLIFIELD. It is a stairstep of development up to the point where you would get what I would call a large size economic type of reactor. Therefore, if you are talking about the pressurized water types, for instance, we already have Shippingport which I conceive as being a prototype. It is about 60,000 kilowatts. It is obvious if we are going to talk about prototype in the pressurized water field, it might be a step up to 100,000. Let us not say 100,000, because we hope to bring Shippingport up to 100 megawatts by a change in cores. Let us say 150 megawatts. Then it would only be a prototype if we thought in advance that this would be an advancement of the art, but not yet reach the plateau of economic conventional competitive costs. It might be that we might think that the 300,000 kilowatt

capacity would reach that. If we would have to build the intermediate size before we got to the full scale size—what we would consider full scale from an economic standpoint in that particular type. When we use the term "prototype" it is very important that we use it in relation to the status of the art at a particular time. There are other types of reactors which are not as far advanced as the PWR or even the BWR. In those areas, I would conceive the size of the reactor as being quite small. It might be between this type of reactor and that you are talking about or 15,000 to 30,000 kilowatts.

Mr. LINSENMEYER. That is right; 20 megawatts I believe is the figure.

Representative HOLIFIELD. 15 or 20 megawatts, because it is in the early stages of development.

Mr. LINSENMEYER. However, as we point out, we believe after it is in operation its potential could be pushed up to 50 or 60 megawatts. That has been the experience with the other boiling water types.

Representative HOLIFIELD. That is true. There is a reasonable degree of justification for that speculation. But it is speculation.

Mr. LINSENMEYER. Expectation, I prefer to say.

Over the past year and a half, due to our corporate position in the heating field, we have been studying seriously the possibilities of applying nuclear energy to process steam and space heating. We have been working on a design of a process steam reactor and have developed detailed cost information for a specific plant to be installed at a chemical company in the Middle West. Our analysis, assuming a reasonable fuel cycle life, indicates that once such a reactor has been successfully operated over a reasonable period of time it will be able to produce steam at competitive rates for a substantial portion of the American market. With cost reduction that can be expected to materialize with succeeding plants, we foresee an immediate commercial market for atomic energy in the United States. Such a market would do a great deal to stimulate a healthy, unsubsidized atomic energy industry in this country and indirectly expedite economic electrical power generation.

As has been stated in earlier testimony, the process steam user is faced with a problem different from that of the electric utility operator. He must be assured of the absolute reliability of the nuclear plant, since the cost of steam constitutes only a small percentage of the total cost of product, and any interruption of the supply of steam would be disastrous to production. The purchaser must also have definite assurance by demonstrated experience that the true cost of the plant and the savings to be accomplished are real and not artificially low by virtue of unrealistic guarantees.

Because of these factors it is not practical for the process steam users to build nuclear steamplants under the same ground rules that apply to the utility industry. In effect, the process steam user must be shown in advance that the nuclear plant he is going to buy will perform with equal reliability to and at lower costs than fossil fuel steamplants.

Since the process steam field represents perhaps the most promising immediate area for the commercial use of atomic power in the United States, I believe the Government should give serious consideration to the development of an invitation that would actually see process steam-

plants constructed. There appear to be several possible alternatives:

(1) The Commission, as Chairman McCone has testified, could elect to construct a process steamplant at a Commission site.

(2) Erect a plant at a Government installation as a replacement plant for an obsolescent conventional process steamplant.

(3) Install a plant at an air base where conventional fuel costs are excessive.

(4) As suggested in other testimony, last week, install a plant adjacent to an industrial plant and sell the steam under contract.

If any of these arrangements are acceptable, it is suggested that the plant be operated under a contract with a typical process steam user to develop the necessary cost and information on reliability to demonstrate the desirability of future installations. A few such plants, whose reliability and competitive operating costs have once been satisfactorily demonstrated, would open the way to a self-supporting nuclear process steam business.

Finally, we believe that in the selection of a reactor type for a process steam plant the same criteria for advancing reactor technology should apply as in the case of a prototype plant for power generation. In this way, the information obtained would be applicable to the scaleup of these reactors for electrical generating purposes as well as using the same reactors as the most advanced full scale models for process steamplants. The Government would, therefore, accomplish at the lowest possible cost many of the same basic objectives projected for the power demonstration program, and at the same time open the doors for a substantial self-sustaining nuclear activity in the process steam area.

Mr. Chairman and gentlemen, I want to thank you again for inviting me to testify and I will be very happy to answer any questions you may have.

Chairman ANDERSON. Are there questions from committee members? Mr. Hosmer?

Representative HOSMER. Would you explain, Mr. Linsenmeyer, how this variable moderated principle works?

Mr. LINSENMEYER. We vary the level of water around the fuel element itself, and that is a very effective way of regulating the heat output of the fuel cell, just the same as the insertion of a control rod in the more conventional boiling water reactor.

Representative HOSMER. As you push the level up, what happens?

Mr. LINSENMEYER. Going up the output would increase. In case of a disaster, you would pull the plug at the bottom and drain the moderating water out of it, which would deactivate the fuel cell.

Representative HOSMER. Unless you operate, then, at a pretty high capacity, you are going to burn out the lower segments of your rod, and not the upper.

Mr. LINSENMEYER. As a matter of fact, it gives you a wonderful prospect, so the technicians tell me, of utilizing the fuel cell to capacity. As your burnout goes on in the lower sections, you raise the whole level and it gives you a much better utilization of the fuel cell assembly as a whole.

I must confess to you, Mr. Hosmer, these are, let me say, expectations, because a VMR reactor has not been built or operated.

Representative HOSMER. I am wondering how you could raise your level at high speed, in case you have to scram the reactor, compared with the present control rods.

Mr. LINSENMEYER. The operating zone, let me say, around which the reactor will float, at a given boiling water rate is a relatively small variation in inches of water level. Incidentally, the water that moderates is not the water that is boiled and fed to the turbine. It is the same kind of water. It is just plain ordinary water. But the moderating water is not boiled off. It is a separate chamber or compartment, inside this vessel.

Representative HOSMER. That has to be maintained at a very high pressure.

Mr. LINSENMEYER. It would be at whatever pressure the boiling water reactor is operating. The moderating water would be at the same pressure as the steam fed to the turbine, but not being boiled. I would have to have a cross section of this thing to explain it more fully to you gentlemen.

Representative HOSMER. I am just a little bit curious as to how you would get an extremely rapid control at that level. Apparently your people have not worked that out yet.

Mr. LINSENMEYER. We have no particular fears along that line. As a matter of fact, if I can indicate a personal fear, it is that the thing will be too sensitive and too quick in operation.

Representative HOSMER. Your fuel element and the degree of enrichment can be substantially what it is in any other boiling water reactor?

Mr. LINSENMEYER. Yes, except as explained in here they do not have to be built so accurately. They don't have to have this accurate position with reference to the control rod, which is one of the real great expenses in building a reactor.

Representative HOSMER. I am talking about the fuel elements themselves. They would be substantially the same.

Mr. LINSENMEYER. Yes.

Representative HOSMER. The difference is in your way of controlling reactors.

Mr. LINSENMEYER. That is right.

Representative HOSMER. Have you made a definite proposition to Wolverine Electric?

Mr. LINSENMEYER. We have been discussing it with Wolverine Electric and we propose to go to the Commission, as I understand it, with a joint proposal at which the proposing parties are Wolverine and American-Standard.

Representative HOSMER. Have you fixed a cost for your operation?

Mr. LINSENMEYER. I have seen something in the way of figures, but these are some rough estimates.

Representative HOSMER. What is it?

Mr. LINSENMEYER. Let me put it in this way: It is about $350 an installed kilowatt.

Representative HOSMER. That is bringing it down a little bit.

Mr. LINSENMEYER. Yes. I might add, Mr. Hosmer, that I was enjoined against giving an accurate cost. These boys who figure these things are a bit cautious, I must say. But there is going to be

a certain amount of speculative risk on the part of our company, and we are willing to accept it in order to get into this market.

Representative HOSMER. Wolverine says they don't want to be subject to any of this risk. Would you accept it all in case your costs are higher than you believe?

Mr. LINSENMEYER. You mean operating penalty, or capital penalty?

Representative HOSMER. The previous witness says that he wants to buy steam at a fixed cost more than anything else. I suppose your offer would have to be somewhere within that standard, would it not?

Mr. LINSENMEYER. I would expect so, yes.

Representative HOSMER. You are prepared to assume all the risk?

Mr. LINSENMEYER. Let me say this, Mr. Hosmer. American-Standard is willing to accept a proper risk that any company must expect in breaking into a new marketing and product area. No matter what new product we introduce, from bathtub to power equipment, we have a certain penalty we pay for capturing a market with a new product. Until this proposition is finalized and the actual figures are laid down, it is difficult to quote any accurate figures.

Representative HOSMER. I just wanted to know if this proposed system could be tested out in one of our existing experimental boiling water reactors?

Mr. LINSENMEYER. Not without a considerable modification of the reactor.

Representative HOSMER. Thank you.

Chairman ANDERSON. Mr. Van Zandt.

Representative VAN ZANDT. I am interested in a statement you made on page 5:

> Process steam users must be shown in advance that the nuclear plant he is going to buy will perform with equal reliability to and at lower costs than fossil fuel steam plants.

Have you any information on the success the Swedes have had to date with their nuclear reactors constructed and operated for space heating purposes?

Mr. LINSENMEYER. I do not have. Some of our people may have, Mr. Van Zandt. I can say, though, on the question of using process steam, the thermodynamics of the situation are on your side with a nuclear plant. That is not true in the case of power generation.

Representative VAN ZANDT. Can you give us a comparison from a cost standpoint, using fossil fuel?

Mr. LINSENMEYER. Some preliminary figures that we ran off in connection with this chemical plant which we mentioned, which is the Michigan Chemical Co., incidentally, indicated 85 cents a thousand pounds for steam, which is approximately their current cost.

Representative VAN ZANDT. That is fossil fuel.

Mr. LINSENMEYER. No, I am talking about a VMR boiling water reactor supplying steam for evaporating water out of salt.

Representative VAN ZANDT. Are you familiar with the comparable costs as far as fossil fuels are concerned?

Mr. LINSENMEYER. That is approximately their current cost. They are presently burning Michigan coal as fuel.

Representative VAN ZANDT. It is competitive, then?

Mr. LINSENMEYER. Yes, in the case of process steam, which we are discussing here. We must, however, point out that the same relation does not necessarily exist in the case of steam used for power generation.

Representative VAN ZANDT. That is all, Mr. Chairman.

Representative DURHAM. How far have you gone in proving the idea of operating this plant without control rods? Do you feel pretty sure about that at the present time?

Mr. LINSENMEYER. I personally do, Mr. Durham. The men who have developed it cannot see anything possibly wrong with it. The parallel principles have been demonstrated.

Representative DURHAM. It would be quite a saving in the cost of the facility.

Mr. LINSENMEYER. The major saving is in the head of the pressure vessel itself. You don't have this expensive packing around the point of control rod entry. You can make a normal pressure vessel as you would in the case of any other boiler or tank.

Representative DURHAM. You have not actually demonstrated the fact yet.

Mr. LINSENMEYER. We have not, Mr. Durham.

Representative DURHAM. Are you going to continue that?

Mr. LINSENMEYER. We have a proposition before the Commission now which will carry this thing considerably farther than we have. I might say that we have put an awful lot of money into it—about all we can put into it short of actually building one.

Representative DURHAM. What is the theory here?

Mr. LINSENMEYER. I beg your pardon?

Representative DURHAM. What is the theory? How does it work without control rods?

Mr. LINSENMEYER. You simply use water itself as the moderating means by varying the water level around the fuel cells, instead of poisoning the activity by the insertion of control rods. Water itself is an effective moderator.

Representative DURHAM. It has a hermetic cutoff.

Mr. LINSENMEYER. It has all the possible safety means in case something runs away, in the same way that a control rod unit would.

Representative DURHAM. This is a very interesting theory. It is an advance over and above anything that has been in the picture for the last few years.

Mr. LINSENMEYER. I would not want to quote the Commission or its technical people, but I think they are very much intrigued by the idea, and would like to see it pushed farther.

Representative DURHAM. That is all, Mr. Chairman.

Chairman ANDERSON. Maybe you would submit to us for the record a statement of the nature of your proposal, because this is a very interesting proposal.

Mr. LINSENMEYER. We will do so.

STATEMENT BY WOLVERINE ELECTRIC COOPERATIVE REGARDING THEIR PROPOSAL TO CONSTRUCT A NUCLEAR REACTOR

FEBRUARY 25, 1959.

Hon. CLINTON P. ANDERSON,
Chairman, Joint Congressional Committee on Atomic Energy,
Senate Office Building, Washington, D.C.

DEAR SENATOR ANDERSON: You requested at the conclusion of our testimony before your committee on February 24, 1959, that we submit for the record our proposal to construct a nuclear reactor. In response to this request we submit the following summary of the major provisions of our forthcoming proposal. It is our intention to present to the Atomic Energy Commission about the middle of April 1959 a complete proposal giving the details of the nuclear powerplant and the type of financial assistance required.

In summary, the major provisions of our proposal will be as follows:

A. TYPE OF NUCLEAR POWERPLANT

The powerplant will utilize a direct cycle boiling water reactor system in which the steam from the reactor passes through a separately fired superheater directly to the turbine. The plant will have a capacity of 20,000 electrical kilowatts net output. The reactor will be of the variable moderator controlled type as developed by American-Standard. This reactor was selected because our evaluation shows that it has the best potential to produce economic nuclear power on the Wolverine system in the near future.

B. TYPE OF ASSISTANCE REQUIRED

1. Capital cost

Wolverine Electric Cooperative obtains its financing for power generating facilities from the Rural Electrification Administration. As a result of the negotiations on our former proposal submitted in 1956 between the Atomic Energy Commission, the REA, and Wolverine, we understand that the REA cannot lend any funds on plant facilities which cannot be justified as being equipment that would normally be used in a conventional powerplant. In addition, Wolverine is not in a position to finance any portion of a powerplant not covered by an REA loan.

As a result of the above, we intend to request the AEC to furnish funds for the construction of the nuclear steam producing facilities including the superheater and such additional funds as may be required to cover the costs of special equipment in the turbogenerator system which the REA cannot finance. We would propose that the AEC retain title to those portions of the system for which they supply funds.

2. Operating costs

Since Wolverine must certify to the REA through their engineers that the intended plant will produce economic power, and since they have no provisions in their financial structure for support of increased operating costs over conventional plants, Wolverine intends to request that the AEC sell steam. The price at which steam would be purchased from the AEC would permit electricity to be produced at a cost equivalent to the cost at which a conventional plant could produce electricity at the same location. The exact formula for this will be a matter of negotiation.

Wolverine will propose to negotiate an agreement with the AEC for operation of the nuclear powerplant.

3. Research and development costs

Although the variable moderator reactor is based on well-known boiling water reactor technology, there are certain aspects of the design which will require research and development. The Wolverine project would then become the first operating prototype of this low-cost nuclear system.

We will propose that the AEC furnish funds to carry out the required research and development.

4. Wolverine and American-Standard contribution

Wolverine will provide the site upon which the plant will be constructed and certain emergency power facilities now available at the proposed location.

American-Standard has, at its own expense, developed the variable moderator reactor concept to the point where we believe it can be applied to a particular

project with reasonable expectation of success. Considerable research and development expense is necessary from this point forward to apply the design to a particular condition of steam rate and pressure. It is expected that the AEC will underwrite this particularized research and development.

When the detailed research and development work for this proposed installation is advanced to a point where the pressure vessel, fuel unit, and other components can be estimated, American-Standard will submit a firm price on these physical elements and take full responsibility for their effective operation.

It is our understanding that the above arrangements are similar to the Elk River project. In the Elk River project a precedent has been established as far as the REA is concerned.

We appreciate your interest in our proposal. We firmly believe that the system we are proposing will be a major step toward the development of economic nuclear power for systems such as ours. As you know, Wolverine has been anxious to cooperate in the development of nuclear power and would appreciate your assistance in obtaining authorizing legislation which would permit our participation. Thank you for your consideration.

Very truly yours,

JOHN N. KEEN,
Manager, Wolverine Electric Cooperative.
JOHN C. LINSENMEYER,
Executive Vice President,
American Radiator & Standard Sanitary Corp.

Chairman ANDERSON. I would appreciate your doing it.

Mr. LINSENMEYER. Yes, sir.

Chairman ANDERSON. Are there additional questions? If not, thank you very much.

Mr. LINSENMEYER. Thank you.

Chairman ANDERSON. Mr. Romney.

STATEMENT OF MILES P. ROMNEY, MANAGER, UTAH MINING ASSOCIATION, SALT LAKE CITY, UTAH

Mr. ROMNEY. I am Miles P. Romney, manager of the Utah Mining Association. I appreciate the opportunity to appear before this committee and discuss a few observations pertinent to the present program of the Atomic Energy Commission as it affects raw materials producers.

The first relates to foreign purchase contracts.

The 1958 "Annual Financial Report" of the U.S. Atomic Energy Commission states on page 12:

> The Commission also has long-term commitments through 1966 for the purchase of concentrates and orange oxide from Canadian and overseas sources.

The domestic industry is very much interested in those commitments, as to quantity, time and price factors.

However, to date, the principal information regarding foreign contracts and commitments has been gained from publications originating outside of the United States.

The November 28, 1957, issue of the Northern Miner, Canada, advised that United States and Britain had advanced funds totaling 67 million pounds sterling and had given contracts terminating from 1963 to 1967 to South African producers.

The February 1959 issue of Engineering and Mining Journal, page 120, states in regard to South African contracts:

> Contracts begin to expire in 1965 and all will be finished by 1969.

Have South African contracts been extended 2 years during the interval between the two publications, or were both only partially informed as to the facts?

The Northern Miner on November 28, 1957, also states that Canadian contracts calling for about $10 per pound, are about to expire by 1963; that the Eldorado Mining & Refining Co. (acts as agents for AEC in Canadian contract relationships) has options on further production through 1966 at $8 per pound; and that the United States reserves the right to accept no more than 500 tons annually from any one producer at $8 per pound. This source then adds the further significant comment:

> The standard price in Canada, for other than contracts calling for premium prices, remains unchanged at $6 per pound U_3O_8 plus a development allowance of $1.25 per pound for the first 3 years.

Regarding the AEC options the Northern Miner of May 15, 1958, states:

> Uniform option clauses are to be written into the contracts of all the Canadian uranium producers * * *. As matters now stand only the later contracts have firm option clauses which permit Eldorado Mining & Refining Co. to claim the mine's production from the end of the contract period, which for most mines is March 31, 1963, to December 31, 1966 * * *.
>
> The significance of this move has not been indicated. Uranium optimists, however, take it as a sign that the United States plans to take up its options on production when the time comes. It has until March 31, 1961, to declare its intentions of whether or not the options will be exercised.

The Canadian uranium producers have apparently decided to press the decision 2 years ahead of the required statement of intention by the United States, for the American metal markets of January 15, 1959, stated:

> Twenty-two Canadian uranium producers urged the Federal Government to take steps designed to insure markets after the expiry of present contracts in 1962 and 1963.
>
> In a brief * * * the Government was asked to take the following action:
>
> Do everything in its power to have the United States exercise its options on Canadian uranium production up to December 31, 1966, and to give, at the earliest possible date, notification of its intention to do so.

We urge that the basic provisions of contracts on uranium between the United States and foreign producers or agencies be released, particularly as to the term of such contracts; volume of yearly purchases; price and price adjustment provisions; financing commitments, if any; and options or commitments for extensions of time or for the adjustment of other specific terms.

Representative DURHAM. Have you requested that from the Commission?

Mr. ROMNEY. We requested that a year ago, sir, in the testimony before the committee. We personally have not directed that specific request to the Commission.

Representative DURHAM. Why not?

Mr. ROMNEY. Because we have been told that such material was classified.

Representative DURHAM. You have a right to request it from a Government agency. You are a citizen of the United States. I don't see why they should not answer if you request it.

Mr. ROMNEY. Personally I have not made that specific request, sir.

Representative VAN ZANDT. At this point I think it is well to mention that we have had hearings on this matter of raw material, and I understand today a portion of the testimony will be released to the press.

Mr. ROMNEY. It will be released today, sir?

Representative VAN ZANDT. I think you will find in the statement some information that will be very helpful to you.

Mr. ROMNEY. We would be very happy to have all that information that is available. We have seen a minimum amount of it in any domestic releases.

Representative DURHAM. The reason I raised the question is the fact that I do not see why American private enterprise should not receive the information unless there are some things secret about the agreements we have with other countries. It is public knowledge, or it should be. It certainly should be available to members of private industry here in the United States. I see no reason why it should not be done.

Representative VAN ZANDT. Mr. Romney, a staff member will furnish you a copy of the statement being released today.

Mr. ROMNEY. Thank you very much. It is probable that some of our questions will be answered specifically here, and we would greatly appreciate it. I have discussed these matters informally with Mr. Johnson, but I have never asked him for a specific and complete itemization.

Representative HOLIFIELD. I might say at this point that we have had a number of meetings with Mr. Johnson and with the Commission on this problem. All of the members of this committee are interested. We have some members who are from New Mexico and Utah and Mr. Aspinall, and formerly Mr. Dempsey and Senator Dworshak. All these men are from the mining areas, and they are watching this very closely. This committee has requested the Atomic Energy Commission to put a green flag on any of these contracts, and not to renew any of these contracts without prior consultation with the committee and giving us their thinking on the subject. We believe that we have a duty to watch our own domestic ore production and milling operation and to look at it in conjunction with anything that we buy outside of the country with dollars. I think you will find that this committee will be very alert on this subject. I am sure in my own mind that there have been no renewals of contracts within the last couple of years or any action that I know of that would be along the line of extending foreign source contracts.

Mr. ROMNEY. We have had no intimation, sir that renewals on extensions have been made. However, we see the definite indication of pressures being put on to make substantial commitments and extensions of those contracts. It is purely in the interest of the point that you are making that we wish to express ourselves.

Representative HOLIFIELD. I am not critical of your statement at all. I just want to give you some assurance that the committee is also interested in this.

Mr. ROMNEY. I appreciate that. That comment could very well preclude the necessity of my repeating the rest of the portion of this statement dealing with such contract extensions because that material is specifically about the matter you spoke of. We have dem-

onstrated a terrific potential for development in this country in the last few years. We do not wish to see any foreign contracts nullified, but we do wish to see at the end of those contracts as full a recognition of the domestic capacity to produce as is possible and is consistent with the overall position.

Representative DURHAM. I was trying to get an idea from the statement that you read your chief complaint, which was the fact that you were not receiving factual information from the AEC. I have great confidence in Jesse Johnson. He is an experienced mining man and has been for years before this thing ever got started. I have had a lot of experience with him on these problems. Of course, if the American mining industry is not receiving full information as to the operation—there is no way for us to prevent Canada or any other country from selling their product in this country—I do think you are entitled to full information.

Mr. ROMNEY. We have definitely felt a lack of information. We have also developed a great admiration for Mr. Johnson.

Representative DURHAM. You should have knowledge beyond a 12- or 18-month period. You have to have knowledge long beyond such a period.

Mr. ROMNEY. That is right. The production data has been released and we have had that data for the last several years. The data so far as contracts in other areas have been most difficult to get. On the basis of what you have just said, Mr. Holifield, I am going to skip the rest of my presentation so far as foreign purchases are concerned.

Representative HOLIFIELD. However, your complete statement will be printed in the record.

Mr. ROMNEY. We appreciate that.

Representative HOLIFIELD. I would not want what I have said to indicate that the United States would preclude itself from foreign sources in case the overall situation demands it. This could result from several different causes. I would want you to be assured that this committee will certainly look at the overall program and we will have a strong concern with regard to the fate of our own domestic producers and millers.

Mr. ROMNEY. That was the viewpoint I had interpreted from you, sir.

Representative ASPINALL. May I make one suggestion, Mr. Romney? On the next to the last sentence on the first page, I wish you would check the source of that statement. It is so apparently wrong from the information we have.

Mr. ROMNEY. "Contracts begin to expire in 1965 and all will be finished by 1969"? Yes, sir; I noticed the glaring discrepancy there. That was in the February issue of the Engineering and Mining Journal which just came to my desk 3 or 4 days ago. I will check on their source and will send you a note as to their reply. Those are the things that leave us in the air as to what the true situation is. I would like to address myself to another matter just briefly, and that is the matter regarding milling contracts, particularly the matter of providing extension of milling contracts through 1966.

(A letter dated April 2, 1959, from Mr. Miles P. Romney, regarding the above discussion is hereby made a part of the record:)

UTAH MINING ASSOCIATION,
Salt Lake City, Utah, April 2, 1959.

Hon. WAYNE N. ASPINALL,
House Office Building, Washington, D.C.

DEAR MR. ASPINALL: In reference to my statement before the Joint Congressional Committee on Atomic Energy of February 24, you questioned the dates of termination of South African contracts as quoted in my statement from the Engineering and Mining Journal of February 1959; i.e., "Contracts begin to expire in 1965 and will be finished by 1969."

In response to your question, I offered to write that publication and request documentation of that statement.

Mr. Alvin W. Knoerr, editor of the Engineering and Mining Journal, replied to my inquiry as follows:

"The statement which we published was inaccurate."

Very truly yours,

MILES P. ROMNEY, *Manager.*

The AEC notice of May 24, 1956, was to provide extension of the purchase program to December 31, 1966. Extension of mill contracts to cover that purchase extension was an inherent obligation. The notice of November 24, 1958, stated:

The Commission will carry out its May 24, 1956, commitment with respect to ore reserves developed prior to this date (refers to ore developed to November 24, 1958. Approximately 84 million tons) in reliance upon the May 24, 1956 announcement by negotiating for the purchase of appropriate quantities of concentrates derived from such ore reserves during the 1962–66 period—

and—

Protection will be given the independent miners by incorporating in all new milling contracts and extensions to existing milling contracts provisions designed to provide independent mineowners a fair share of available milling capacities.

We appreciate the fact that problems of definition and application made mill contract extensions difficult under the May 24, 1956, program, but with those matters removed by changes incorporated in the November 24, 1958, program, mill contract extensions should be undertaken promptly and completed with as little delay as possible.

A tabulation of "Uranium Processing Plants" issued January 15, 1959 by the AEC Grand Junction office shows but 3 of the 23 plants listed as having contracts continuing to 1966. One new mill contract not listed on the above tabulation also continues to 1966. Recent news releases indicate two others on that list are negotiating for such extension. Thus, only 6 of 24 contracts have been continued to 1966 or are negotiating for such extension. Several mills have been negotiating for such an extension for nearly 2 years. For the better part of the past year, completion of such extensions has been delayed again and again by technicalities, policy indecision, apparently conflicting lines of authority and over concentration of decisions at the top level here in Washington.

Those are comments that have been given to me by the various milling operators who have been in the process of negotiating for extensions.

We again urge near-future processing of all domestic milling contracts for extension to 1966 and also again urge that negotiations once started be expeditiously completed. Both the mills and the inde-

pendent miners they serve suffer from restriction on their abilities to plan future operations while extension contract provisions remain uncertain.

Representative DURHAM (presiding). Are there any further questions?

Representative HOLIFIELD. I want to say that this last point you brought up here is something that we might well inquire about, because these people should have notice of a reasonable extension of their contracts if they are ging to go ahead with them in order to do their own planning.

Mr. ROMNEY. The program is designed through 1966. All the purchasing will be done through the mills. The shippers have to depend on those mills as an outlet, as a source outlet, for their ores, and without those mills having any firm contract, they cannot enter into a firm contract with the mine operators who are dependent on them.

Representative HOLIFIELD. Is it your understanding that the contracts run until 1966?

Mr. ROMNEY. There are only three mills who now have contracts extending through 1966. Others terminate at varying dates up to 1962–63. But we believe it is the inference in the May 24, 1956, announcement extending the purchasing program, and also inherent in the most recent announcement that milling contracts would be extended through the 1966 period. All those mills which have been authorized would be extended through the 1966 period.

Representative ASPINALL. I think you realize, Mr. Romney, with this recent cutoff date that we have some very difficult situations to take care of as far as independent producers are concerned, and the captive mill producers are concerned. You would rather that they take a little bit more time in order to see that the equities are established at least favorable to the independent producers; would you not?

Mr. ROMNEY. Certainly we would wish them to be completed as expeditiously as possible considering the circumstances, and the conditions which exist. In the time between the two announcements of the program there was a great deal of confusion in the industry as to what the situation of the mills would be. With the recent announcement of the program we feel that the situation has cleared up so that those contracts can be gone into and arranged expeditiously. We are not saying that any time limit is a measure of that, sir. It is simply a matter that we urge that they proceed expeditiously on the negotiation of those contracts.

Representative DURHAM. Didn't we make 5-year contracts from the time of production when most of the producing mills were beginning?

Mr. ROMNEY. Those contracts varied in time, sir.

Representative DURHAM. I know that they varied.

Mr. ROMNEY. Yes, some of the mills in New Mexico are terminating in 1962 or 1963, and were just completed a year or so ago. They were relatively of short range.

Representative HOLIFIELD. In fairness, I think the record should show that most of those contracts were made on a 5- or 7-year amortization basis. The mills got back the cost of the mills in their contracts. There is that to be taken into consideration. Some of these mills since the original mills were built are also built on certificates

of necessity which allow rapid amortization. Those that have been protected need less protection than those who are still in the period of amortizing their capital costs. So there are a lot of factors to be considered in this matter. Also, of course, the cutoff of need to a certain extent.

Mr. ROMNEY. I appreciate that amortization was taken into consideration on all of these mills. I am speaking from the viewpoint of the mill as the outlet for the ore in the area. The mill is unable to contract with the mine beyond the period of its existing contract with the AEC. But the AEC has made a commitment with certain provisions to continue a purchasing contract through 1966. Until the mills themselves have contracts on which to back contracts with the miners, the miner is left high and dry. I am not pleading the case of the mill any more than I am the miner, sir.

Representative DURHAM. Thank you very much. Mr. Romney.

Mr. ROMNEY. Thank you, sir.

Chairman ANDERSON. The next witness is Mr. John W. Simpson, general manager, Bettis Plant, Westinghouse Electric Corp., Pittsburgh, Pa.

STATEMENT OF JOHN W. SIMPSON, GENERAL MANAGER, BETTIS PLANT, WESTINGHOUSE ELECTRIC CORP.

Mr. SIMPSON. Thank you, sir.

Mr. Chairman, I am John W. Simpson, general manager of the Bettis Plant of the Atomic Energy Commission operated by the Westinghouse Electric Corp. I welcome this opportunity to appear before the committee and discuss the PWR—the Shippingport Atomic Power Station. First, I would like to summarize quickly some of the vital statistics of the plant although many of them are well known to you.

The Atomic Energy Commission assigned primary responsibility for the design, development, and construction of the PWR to the Naval Reactors Branch under Vice Adm. Hyman G. Rickover. The Bettis Laboratory was selected and assigned the research and development job under Admiral Rickover's direction.

In the naval program and at Bettis, there was a body of experience in pressurized water reactors dating back to the building of the *Nautilus* and its prototype, from which early design concepts could evolve. But the PWR was somewhat foreign to naval work and was a wholly new development effort. From the past there were points of reference but a new reactor system had to be conceived. The PWR was not designed as a naval reactor but clearly as a civilian powerplant.

Site clearance and construction started late in the winter of 1955. The plant produced its first power on the lines of Duquesne Light Co. on December 18, 1957, and its full 60,000 kilowatts on December 23.

Shippingport has now generated 200 million kilowatt hours of electric energy for the Duquesne Light System and two power runs of more than 1,000 hours each have been accomplished with no difficulties. So much for the vital statistics.

It is not too early to ask if Shippingport is a success. There is enough experience for an objective evaluation.

PWR is the first demonstration in the United States of a large scale atomic powerplant integrated into an electric utility system. As the first power reactor, its successful operation has promoted U.S. scientific and technical prestige in the world.

Thinking of PWR as a power station suggests standard utility measures like mils per kilowatt-hour and this could be an inadequate measurement of success. But as a power station the plant has an ease of operation and a maneuverability far superior to even conventional electric stations. Its self-regulating characteristics make it easy to operate. It is safe, dependable, and a normally usable part of its utility system.

But the true measure of success of the PWR is the value of information and experience in the infancy of atomic power—scientific, technological, operating, manufacturing, safety, and other information.

Shippingport is far more than an atomic powerplant. It is an atomic power laboratory.

It would take volumes to describe in detail the technical information which has been added to the national storehouse of knowledge by this power laboratory. But today, I though I might highlight some of the valuable contributions.

The contributions come from what was learned in designing and developing the plant, from its actual operation and from a continuing program of core development and plant experimentation.

But these are not separate, because unless an atomic powerplant is designed with specific and exacting criteria, precise data cannot be obtained from its operation. In other words, you have to know what you are looking for in order to observe and report the phenomena you see. I cannot overemphasize this point because it represents the reason why you cannot advance reactor art with hit and miss construction schemes—by the so-called go, no-go method. Just building a reactor is not enough.

This and other considerations were the basis of the developmental philosophy of the PWR—of reducing allowable margin of error to a minimum through precision. There was precision in design and the things being learned today have clarity and utility because of accuracy. Shippingport was not just built from the ground up. It is a product of laborious study—research and development.

In most industries technical decisions are based on engineering judgment and this in turn is normally based on experience. When there is an absence of experience you must proceed from the theoretical or on the hit-or-miss basis. The approach through the theoretical was chosen for PWR.

As a result of PWR there is now developing a body of experience in the United States from which engineering decisions can be made. Of course, very much more remains to be learned about water reactors.

An example of one development program was uranium oxide. We searched the literature but there was only limited information on uranium oxide. There was almost no information on UO_2 in pellet form—a shape which appeared to be the most desirable for a long lifetime utilization of the fuel.

After the decision that the PWR would have a seed and blanket core—seed in the form of enriched uranium—a surrounding blanket in the form of these uranium oxide pellets—we proceeded to expand

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the knowledge of uranium oxide characteristics. In test reactors we studied the effects of long burnup and behavior under irradiation. We studied the effects of cladding failures on uranium oxide fuel elements by purposely putting defects in them and having them irradiated for long periods of time to see what occurred. We studied all aspects of its behavior in the presence of heat and its corrosion characteristics.

Representative HOLIFIELD. Mr. Chairman, I would like to stop Mr. Simpson right there. In order to accent this point. If I understand it correctly, you actually forced defects into the fuel elements to see what would happen.

Mr. SIMPSON. That is correct, sir.

Representative HOLIFIELD. In your test reactor at Idaho?

Mr. SIMPSON. In the materials testing reactor at Idaho and in the test reactors at Chalk River in Canada. There are many things you can learn by putting a defect in. Fission products, which are formed when all fission takes place, are inside the uranium oxide. We wished to determine the rate at which the fission gases came out of the oxide and out through various size holes and into the coolant stream. We wished to determine what happened if the water went into the fuel and boiled in there. We wished to determine the chemical effect of the water in association with the uranium oxide and with the fuel element cladding.

Representative HOLIFIELD. And the degree of contamination which would occur in the whole system in case there was a rupture of the fuel element?

Mr. SIMPSON. That is right. That was one of the important aspects. In order to do that you had to have a number of rods and a system which had the right scale up to represent a complete reactor.

Representative HOLIFIELD. As I understand, this very precautionary procedure—if I am wrong I hope you will correct me—has not been carried out on some of the other types of reactors which are being constructed. I have reference to large-scale reactors that are being constructed at this time.

Mr. SIMPSON. I am, of course, more familiar with the reactors on which I worked than the others. Therefore, I can only give you an impression, sir. But it would be that more developmental effort went into the PWR reactor than most other comparable reactors. I am not an expert on exactly what others have done.

Represenative HOLIFIELD. I was very much concerned about the location of these reactors, and I still have that concern—these large reactors—close to large populated cities. This is one of the reasons why I was in a very small minority, I will admit, in opposing the indemnity bill 2 or 3 years ago. I thought that the element of care in imposing regulations on the safety factors and the element of care in choosing the sites in isolated positions, as was provided for in the Gore-Holifield bill for large-size reactors, was a very important matter. I still think it was very important. I just hope that I was wrong in my extreme concern at that time because I certainly would not want anything to happen in the future, nor do I indicate that anything will. If these other reactors have not been tested to the point of deliberate rupture of fuel elements, we still don't know what would happen if one did occur.

Mr. SIMPSON. As indicative of what one can learn with extensive tests, we did learn that the different fission products because of their different chemical properties come out in different proportions. Therefore, they have varying effects on the system. We learned how to take this into consideration in the design. We also learned that the density of the uranium oxide was very critical. For example, in the 93 to 94 percent of theoretical density 1 more percent would cut down the amount of fission products that would come out quite considerably. By having done this with a pellet of the type that we intended to use, we were able to keep the density up and know that this was important.

Representative HOLIFIELD. Your point is that you have eliminated a great many of the potential trouble spots by extreme care in your preliminary testing?

Mr. SIMPSON. Yes, sir.

Representative HOLIFIELD. This is why you say that the information that you get is not evolved on a hit-and-miss method but is evolved on an experimental base which you have established?

Mr. SIMPSON. That is correct, sir.

Representative HOLIFIELD. That is all, Mr. Chairman.

Mr. SIMPSON. A very major developmental effort went into learning how to manufacture the pellet. For example, uranium oxide had to be compacted under pressures of 125 tons per square inch to make pellets. Normal industrial powder metallurgical practice rarely exceeds 75 tons.

Representative DURHAM. Did you do that at Bettis?

Mr. SIMPSON. Yes, sir. For the first core of the PWR the pellets were compacted at Bettis.

Representative DURHAM. At 125 tons?

Mr. SIMPSON. Yes, sir. As a pressure it is not extremely high. It only becomes high when related to the specific oxide that is being compressed and the ability of the oxide to flow in the compressor, and so forth.

Representative DURHAM. They stood up?

Mr. SIMPSON. Yes, sir.

Representative DURHAM. The more pressure you can get into them the longer the life is prolonged?

Mr. SIMPSON. The more pressure the greater density, and by compacting you can reach a density between 60 and 70 percent. Even this does not insure enough density so we sintered them in furnaces at 1,750° C. to raise the density to 75 percent so you can get more uranium and prevent the fission gases from getting out.

Representative DURHAM. That also increases the efficiency of the heating system?

Mr. SIMPSON. It gives you somewhat higher heat conductivity in the oxide, yes, sir; and holds down the central temperature in the pellet which is a very important consideration. Even after the compacting and sintering the pellet diameters had to have tolerances of 1 part in 5,000. These fuel manufacturing techniques have been perfected and today the techniques belong to all industry.

From the physics standpoint, uranium oxide presented equally challenging problems. We inaugurated a physics program to learn how to carry forward the design of a low enrichment high uranium

oxide content core moderated by water. This was the first time a reactor of this kind had been designed. We had to learn how to calculate nuclear properties and predict behavior.

Operations have verified that physics calculations were accurate and the plant has operated as the physicists predicted.

Representative DURHAM. That was done altogether on a theoretical basis?

Mr. SIMPSON. It was a combination, sir, of theoretical and experimental physics, where we took actual configurations of uranium oxide rods and put them in reactor critical experiments, starting with very simple critical experiments which the physicists could calculate and compare experimental results with analytical results. Then when they corrected their methods they could go to more complex geometries and work on up to where we had an actual full-scale nuclear mockup of the PWR at Bettis before the core was constructed to go into the plant at Shippingport. This was obviously expensive but it also taught us and others much about the physics of this type of reactor.

Chairman ANDERSON. Doctor, the proposal to construct the gas cooled reactor that Kaiser-ACF have worked on in response to a legislative mandate would have some interesting developments on uranium oxide also, would it not?

Mr. SIMPSON. Yes, sir. They would use uranium oxide. They will build on the work we have done and subsequent work that is being done now and has been done at both the Argonne National Laboratory and Oak Ridge National Laboratory.

Chairman ANDERSON. They will have the great value on all the preliminary work that has gone on uranium oxide?

Mr. SIMPSON. That is right. Despite the fact that it is a gas reactor instead of a water reactor, much of the physics work that was done is germane to thermal reactors broadly, not just to water reactors. It is a matter of the neutron energy spectrum rather than just the moderator and fuel.

Chairman ANDERSON. If it were to be built, could full information be obtained on an experimental basis or should it be hooked up to power to find out how it worked?

Mr. SIMPSON. From a technical viewpoint the important thing is to know precisely what you have designed, to have instrumentation in there which will determine what is taking place within the reactor. When you have the facts about what you expect will take place in a reactor and can compare your experiments with it, you have a basis for understanding and determining why variations occur, and you learn the maximum amount. Obviously there are certain features of a reactor that one must try out in connection with a utility system—how it responded to load swings on a utility system, what happens if the breakers trip off and turbine load is dropped and things of that sort.

Chairman ANDERSON. Was that not the very point with the PWR. You wanted a continuous run to find out how it worked in a continuous system?

Mr. SIMPSON. Yes, sir. We have operated it strictly at the demands of the utility system for long periods. Then we have operated it as a test reactor where the utility stood aside and let us run the tests that

we wanted rather than what they would need for their load. We have operated as a base load plant for periods of time for the utility system.

Chairman ANDERSON. Would you obtain the full value of this without running it on the lines?

Mr. SIMPSON. You would not obtain the full value without being part of a fully integrated utility system.

Chairman ANDERSON. I think so. I think it was a very fine piece of work to do it that way.

Mr. SIMPSON. But some of the big things we had to learn were the properties of uranium oxide over a long period of time, what the plutonium content would be and how it would contribute to reactivity. This information is now coming in and soon industry will know to what irradiation levels one can carry a uranium oxide type reactor—how long they will hold up.

All the nuclear reactors on the drawing boards today of the water type, both for civilian power and merchant ships, plan to utilize uranium oxide as a fuel. That is so even in the Soviet program. The continued operation of Shippingport is the only source of lifetime data on large quantities of UO_2 in the world today. You hear of megawatt-days per ton measurements. These are being calculated from the PWR experience, and early calculations are optimistic.

The Oak Ridge and Argonne Laboratories have since started complementary uranium oxide work for reactor applications.

There also had to be much development to learn how to make zircaloy tubing which holds the UO_2 pellets. At the start the only known method was to drill a hole in zircaloy cylinder. This would have cost $100 a foot and 100,000 feet were needed. The cost would have been prohibitive. We had to develop production methods for the extrusion of zirconium alloys. These methods were developed and zircaloy tubing has become essentially an "off the shelf" item today—at a fraction of the earliest predictions of costs.

But the Shippingport reactor is more than fuel and core. The reactor system is made up of large components like the pressure vessel, pumps, valves, and the other things from steam generator to turbine.

A pressure vessel of the size needed at Shippingport had never been fabricated before and this was one of the most complex problems. No mill had ever made bonded sheets of stainless and carbon steel on the scale envisioned. Things like shrinkage during welding had to be predicted to close tolerances. The bottom had to stay exactly round. This combined requirement of high-pressure operation, unprecedented size and high integrity fabrication promoted a big technological advance in pressure vessels.

As a result of this work, reactor vessels of comparable size are now being produced on a much more routine basis for other proposed atomic installations.

The large reactor vessel was typical of many components in the Shippingport plant which were "firsts" in the industry. The huge canned motor pumps required to circulate the coolant were a major step forward from the pumps which had been developed for the *Nautilus*. The castings required for the hydraulic part of these pumps and for main stop valves represented the largest stainless steel foundry work undertaken in the United States up to this time.

Advances were made not only on the drawing board but in the noisy foundries and boiler shops, in machine shops, and in the skills of first class workmen who themselves developed abilities usable in the manufacture of other nuclear power generating and other industrial equipment.

The Shippingport power laboratory provides points of reference for the whole scope of regulatory considerations for civilian nuclear power. When other power reactors are built elsewhere in the United States, the States and the Federal Government must look to the PWR experience.

PWR is a safe plant. Were I to incorporate its same features, I would build a duplicate of the PWR in the center of Washington. In fact, radioactive contamination in the reactor system has been so minimal that special instrumentation had to be installed to detect it. The amount we have detected so far, is one ten-thousandth of the maximum design allowance.

As the AEC has announced, they are now conducting a training school at the site for the on-the-job training of technical people and reactor operators.

Yes, the true measure of PWR success is the measure of what has been learned. Today, I have tried to cover briefly some of the highlights of what was learned and show the incalculable worth of technical knowledge.

Fortunately, there was no failure in our Shippingport designs. But had there been, I could well make this same statement today, because in the early days of any technical program, learning the things you should not do, is as valuable as learning what you should do.

Before long the first seed elements will be removed from the core at Shippingport but the blanket will remain during the lifetime of several seeds. From the blanket much will be learned about reactivity lifetime and irradiation damage to large quantities of natural uranium fuel.

PWR core 2 development is the core program for the immediate future, with its physics, fuel and instrumentation work. Core 2 will have improved instrumentation which will assure even greater information.

The future development program, then, is essentially a core program.

PWR has reserve kilowatt capacity. Admiral Rickover decided to incorporate in the plant a capacity greater than we envisioned as being needed during the early stages of the plant. After core 2 the plant will probably be taken up to its 100,000 kilowatt level and of course no equipment needs to be replaced to do this. The plant could be taken up to a higher kilowatt range right now but this could endanger the information gathering program on uranium oxide.

In essence—we combine reactor experimentation with industrial reactor operation. There is no counterpart to this elsewhere.

The body of information which will be acquired in this fuel program will be of inestimable value. But to learn and to test is expensive. Fortunately, the information obtained is unclassified and available to all industry. The costs of today prorated among the reactors of the future represents a small investment.

In summary, I can report that the PWR is a valuable asset in the atomic power program of the United States. As a nation we can be thankful that the Atomic Energy Commission and the Joint Committee had the vision to authorize the construction of this atomic power laboratory.

Chairman ANDERSON. Mr. Simpson, would you tell us just a little bit about your background? Are you a graduate of the Naval Academy?

Mr. SIMPSON. I am a graduate of the U.S. Naval Academy. I was unable to get a commission because they decided that I could not see well enough, so I went into private industry.

Chairman ANDERSON. What class?

Mr. SIMPSON. Class of 1937. I worked in the navy and marine section of the switchgear division of Westinghouse during the war. Immediately after the war I went to Oak Ridge as part of the Daniels power group with Professor Daniels, working there for 2 years, and came back to Westinghouse and joined the Bettis Atomic Laboratory in 1949.

Chairman ANDERSON. You may not be able to see well enough to get a commission, but you did pretty well from my standpoint. I just want you to know that there are a great many of us in this committee that know a great deal about your work, and we know how wonderfully you have worked with Admiral Rickover. I am very happy that you know that Admiral Rickover is getting a very high medal and recognition, and you are. I would not want the record to close without giving some expression of fact that you have made an enormous contribution to that, and have done it quietly, and we appreciate the fine job you have done.

Representative VAN ZANDT. And we labored with you.

Chairman ANDERSON. As Mr. Van Zandt points out, we labored with you.

Representative DURHAM. I would say that I have been familiar with the doctor's work for a number of years, and I concur with what the chairman has said. You have done a fine job.

Mr. SIMPSON. Thank you.

Representative DURHAM. I think I particularly like the fact that you said on page 8:

> This plant could be taken to a higher kilowatt range right now, but this could endanger the information-gathering program on uranium oxide.

In other words, you want to test these things out, and you would rather want to do that than make a record of how rapidly you went up to a higher pitch.

Mr. SIMPSON. Yes, sir.

Representative DURHAM. This is exactly what we are talking about there in the Kaiser-ACF program of getting an experimental prototype. I am very happy that you have done so. This is a fine contribution. We are all very proud of it.

Chairman ANDERSON. Are there any questions?

Representative HOLIFIELD. Mr. Chairman, I just want to say that I have visited Bettis, Shippingport, on several occasions, and I too want to say that I know something about the fine backup work and original work which Dr. Simpson has done in this field. I think that this is one of the most remarkable statements, and one of the most valuable statements that has been given this committee in a long time.

I want you to elaborate for just a few moments on the annual cost of Shippingport, because there have been statements made that it is costing $20 million a year to operate it. If you do have a breakdown on the difference between your experimental cost of fabricating new cores, and operating the different experiments that you operate, as contradistinct from the operation and maintenance cost which might ordinarily be charged up to kilowatt cost, I wish you would either give it to us, or prepare it and give it to us at a later date. The committee is faced in some instances with criticism by people who do not understand the story for operating the Shippingport plant at a high kilowatt cost. I think the minute you understand that we are not operating it just for those kilowatts, but for the continuous information which we are getting out of the burnup on fuel rods, and the reaction of the different components of the reactor to actual line operation, and you charge off that part of the cost which should not go on operation and maintenance and cost of kilowatts, you get an entirely different picture.

Mr. SIMPSON. I believe I can give it to you today, sir. Of the cost, about 10 percent of the normally quoted cost, which is around $20 million or about $2 million is really operating expense in the normal sense. Of the remainder, about 45 percent is core cost, about 45 percent is strictly research and development cost.

Representative HOLIFIELD. When you say 45 percent is core cost, you mean the fabrication of additional cores and different types of cores?

Mr. SIMPSON. Yes, sir. The additional core will be the culmination of a major development effort. It will be a uranium oxide plate type core with a completely different method of fabricating to determine whether this will be better or not, and to increase the ability to raise the power, because the plates give higher heat transfer area per unit volume.

There will be developmental work done on the physics of the reactor, methods of loading to cut down the flux peaking. There will be a better understanding of the number of control rods required, and the ability to cut down the number. There will be much learned about the irradiation damage of the plate type fuel elements. There will be work done on alternate control rod materials to try to get a cheaper rod than a hafnium rod, that could be put in when the first core has been used up.

Representative HOLIFIELD. So as a rule of thumb, we could say that 90 percent of annual cost is going toward valuable research and development information, and only about 10 percent of it to actual operation and maintenance of the reactor itself?

Mr. SIMPSON. Yes, sir. Even the fuel cost, because it is the first time that such a core has been built, much of the cost is in fact in manufacturing development.

Chairman ANDERSON. Mr. Hosmer.

Representative HOSMER. Doctor, at the Atomic Industrial Forum last November, there was some information from the Duquesne Power & Light people that there were some fuel element failures. Is that borne out?

Mr. SIMPSON. By special radiochemistry techniques of measuring the water, we have determined that there are some fission products in

the water. We believe that there are more than could be accounted for by surface contamination of the fuel. Therefore, we believe that there is probably at least one of the 100,000 rods in it that has a small hole in it. We could have between 1,000 and 10,000 times this amount of leakage of fission products without having any problem in operating the plant.

Representative HOSMER. There is no indication of whether it is in the seed core or the blanket core?

Mr. SIMPSON. It is in the blanket because we do have a fuel element detector that does determine where it is located. We do not know whether it was an incipient defect that was in the fuel rod at the time it was put in or whether it has developed since. It has not changed in magnitude since the early days, however. If the defect is there, and we believe it is, it has remained constant over the last approximately 1 year.

Representative HOSMER. The plant was closed down for a couple of months starting in November. What was the reason?

Mr. SIMPSON. Yes, sir. During the December-January period we were making some nonnuclear tests. We did have a pump that failed, and we had to put the spare pump in. We were making some changes in one of the steam generators to learn more about how the steam separates on the steam side, to learn more about the water chemistry, and things of that sort. There has also been some difficulty with the turbine moisture separator.

Representative HOSMER. How much of the design life of this first core has been used up?

Mr. SIMPSON. For the seed, sir, today we have used up 110 percent of the design life. The design life was 3,000 full power hours. We are now at 3,300.

Representative HOSMER. How about the blanket core?

Mr. SIMPSON. We believe from a reactivity viewpoint, the blanket has almost an indefinite life, because it is driven from the seed and we do not have a reactivity limitation. This is why the seed and blanket concept has given us such a unique ability to test fuel under high radiation, because you do not have to take it out when the slightly enriched fuel is depleted and the reactivity decreases. It is a matter of corrosion failure, mechanical damage of some sort, or irradiation failure, and we are simply not smart enough to put a number on the design life. So far we note nothing to indicate that it was any worse off than it was when it was put in.

Representative HOSMER. Throw out those variables and it would be indefinite.

Mr. SIMPSON. Except for irradiation damage or corrosion or mechanical damage, there is no reason why it can't go for a very long period of time.

Representative HOSMER. At present the seed core is zirconium-clad uranium metal?

Mr. SIMPSON. That is correct.

Representative HOSMER. You say the second core is going to be a uranium oxide core of some kind?

Mr. SIMPSON. The blanket which is in there today is made of uranium oxide pellets in rod form. The second seed will be similar to the first except it will have some boron added to it as a burnable poison

to make it last longer than the present seed. Until we see how long the first one lasts, it is hard to put a number on the second one. The second core will have uranium oxide plates for the blanket replacing the uranium oxide rods. The seed will be an even longer life and may possibly be a uranium oxide plate-type seed with highly enriched uranium in the oxide which then, of course, would require a diluent of some other low neutron absorbing oxide material.

Representative HOSMER. You are not replacing the whole oxide material?

Mr. SIMPSON. Eventually we will.

Representative HOSMER. You are replacing part of it?

Mr. SIMPSON. During the coming summer we will replace the seed. When that seed is burned up, we will replace it. Eventually there will come a time when we will feel that the blanket has to be taken out, at least partly for experimental reasons, or it may have gotten into trouble because of corrosion or radiation damage or some other reason.

Representative HOSMER. Would you get as much information out of a 35,000-kilowatt plant as the one you built?

Mr. SIMPSON. The amount of information you can get out of a plant is determined by the type of plant you have. Some plants are susceptible to scale-up; others are not.

Representative HOSMER. I am talking about this particular type.

Mr. SIMPSON. We have learned some things, for example, about neutron flux tilting in the reactor. The neutron flux is not uniform across the reactor.

Representative HOSMER. Is that the same expression as flux peaking which you mentioned a moment ago?

Mr. SIMPSON. Not exactly, sir. Flux peaking means even in its normal state, even though symmetrical, it may have peaks. When you have a tilt, one side is definitely higher than the other, and you have a variation across the reactor. This varies with the size of the reactor. You are much less likely to have such a phenomenon take place in a small reactor than in the larger one. The larger you go, the more loosely coupled from a neutron point of view the system is, and the more likely you are to have a flux tilt. If you know you have a flux tilt, and if you have instrumentation to determine what it is, it is a simple matter to put the control rod in on one side a little more than the other, and balance it out, and you have no problem. This is a phenomenon that we have learned about at Shippingport. We have been able to run a number of experiments to learn more about this phenomenon.

Representative HOSMER. You would then conclude that you should have built the type you did, and not smaller?

Mr. SIMPSON. That is correct, sir.

Representative HOSMER. I believe that is all, thank you.

Chairman ANDERSON. In other words, you learned something about piping and plumbing, because you build the larger size.

Mr. SIMPSON. And because the core would be different in a small size than in a large size from a nuclear reactor physics viewpoint, we learned in the large size what we would not have learned in the small size.

Representative VAN ZANDT. Mr. Simpson, if you were called upon to duplicate the Shippingport plant today, how many months would it take you?

Mr. SIMPSON. From the standpoint of what, sir?

Representative VAN ZANDT. Months.

Mr. SIMPSON. It took 4 years from the initial start in early fiscal 1954 or the fall of 1953 calendar year, to the fall of 1957. To duplicate, I would guess about 2 years to 2½ years. It takes about a year to a year and a half to procure major components; then it takes about 6 months to a year to get them installed and checked out. Starting from the day you order the pressure vessel, 2 to 2½ years is about the best you can do.

Representative VAN ZANDT. What is the capital investment of the Shippingport plant to date, in round figures?

Mr. SIMPSON. In round figures, I believe it is $70 million.

Representative VAN ZANDT. Could you duplicate this plant for $70 million?

Mr. SIMPSON. Yes, sir.

Representative VAN ZANDT. Less?

Mr. SIMPSON. Less.

Representative VAN ZANDT. Considerably less?

Mr. SIMPSON. I would say considerably less.

Representative VAN ZANDT. Have you had any problems of contamination as a result of the operation of this plant?

Mr. SIMPSON. We have had no problems of contamination.

Representative VAN ZANDT. When are you going to install your new core?

Mr. SIMPSON. The next seed will be installed during the late summer of 1959. This is presuming that our predictions of how long it will last come true.

Representative VAN ZANDT. That is the present core?

Mr. SIMPSON. The present seed. That is part of the core.

Representative VAN ZANDT. The training program you are conducting, what does it mean in persons trained?

Mr. SIMPSON. Let me clarify, sir. This is a training program that the Atomic Energy Commission and the Duquesne Light Co. are running. We participate as advisers, but it is not a program that we are running. I believe there are about 25 people in each of the sessions. They last for about 6 months of which part of it is on the job training, running the reactor, part in classroom study.

Representative VAN ZANDT. Isn't it true the AEC and Westinghouse Corp. have turned out hundreds of technicians in this particular field as a result of the training provided at the Shippingport plant?

Mr. SIMPSON. There will be many turned out in this program. It is running several times a year, overlapping programs, with 25 students in each course.

Representative VAN ZANDT. This is militarywise?

Mr. SIMPSON. These are utility people. There have been many hundreds of military people trained in reactor operation, both at Bettis and Idaho.

Representative VAN ZANDT. What about the utility people? Have they shown great interest by sending personnel there for training?

Mr. SIMPSON. I don't believe I am in a position to give you a real clear answer on that. They were clearly interested in the early days in sending people to the facility at Idaho. I believe the response to this training program has been very good. I don't have any figures on it.

Representative VAN ZANDT. Mr. Simpson, I want to commend you on your statement today. As one who lives in Pennsylvania, and as a member of this committee, I look at Shippingport as a monument to the Research and Development effort in the field of atomic power.

That is all, Mr. Chairman.

Chairman ANDERSON. I am sure we are getting a lot of information from it. Of course, there are some members on this committee who would feel if we had three or four Shippingport plants of different types, we would be getting a great deal of information from other sources, as well. We are very happy that you have given us this fine report to prove how much information is available from this one plant. Thank you, and come back often.

Mr. SIMPSON. Thank you, sir.

(Correspondence clarifying and correcting a statement in the AEC 25th Semiannual Report concerning the performance of the PWR at Shippingport follows:)

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C., February 2, 1959.

Mr. A. R. LUEDECKE,
General Manager,
U.S. Atomic Energy Commission,
Washington, D.C.

DEAR MR. LEUDECKE: In reviewing the Commission's 25th Semiannual Report the following paragraph on page 19 was noted:

"Experience has demonstrated that this type reactor is quite stable and can adjust to large and sudden changes in power load. Its operation does not result in unmanageable radioactivity problems. The primary disadvantages of the system are its low plant heat rate due to the saturation steam pressure and the temperature drop through the primary loop heat exchanger, the necessity for an intermediate heat exchanger, the heavy shielding required over primary coolant loop equipment, and the high cost of the reactor pressure vessel and primary loop components."

These statements appear to be somewhat at variance with statements previously made available to the Committee.

We would appreciate being informed if the Director of the Reactor Development Division and the Assistant Director for Naval Reactors were consulted on these statements and if the statements reflect their views on pressurized water reactors.

Sincerely yours,

JAMES T. RAMEY, *Executive Director.*

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., March 6, 1959.

Hon. CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy,
Congress of the United States.

DEAR SENATOR ANDERSON: Mr. James T. Ramey's letter of February 2, 1959, raised certain questions concerning a paragraph on pressurized water reactors contained in the Commission's Twenty-fifth Semiannual Report to the Congress.

The use of the word "low" in the statement "The primary disadvantages of the system are its low plant heat rate * * * " was an obvious error. High plant heat rate was intended.

The paragraph in question was intended to indicate the limitations of the pressurized water concept for achieving economic civilian power when compared with other reactor concepts which, although not completely proven or demonstrated, appear feasible and promising.

The staff of the Assistant Director for Naval Reactors provided the data used for the section in the report concerning the pressurized water reactor at Shippingport. However, through an oversight, that group was not asked to review the section of the report to which Mr. Ramey's letter refers.

Admiral Rickover has since expressed concern that the statements made in the report may create erroneous impressions on the characteristics and performance of this concept.

The Director, Division of Reactor Development, did concur in the use of the referenced statements.

Sincerely yours,

A. R. LUEDECKE, *General Manager.*

Chairman ANDERSON. Mr. Winterbottom.

STATEMENT OF JOHN J. WINTERBOTTOM, VICE PRESIDENT AND DIRECTOR OF ESSO STANDARD OIL CO.

Mr. WINTERBOTTOM. Mr. Chairman, I have asked Mr. Stewart to join me. He is our naval architect and marine constructor.

Chairman ANDERSON. Thank you.

Mr. WINTERBOTTOM. My name is John J. Winterbottom and I am vice president and director of Esso Standard Oil Co., which company last year acquired all of the assets of Esso Shipping Co., both companies being wholly owned by Standard Oil Co., New Jersey.

Our company owns 34 American-flag tankers ranging in size from the 16,600 d.w.t. T–2 of World War II to four 37,600 d.w.t. tankers. The latest of these was delivered in 1958. In brief, we have the largest privately owned American-flag tanker fleet and one of the most modern by reason of our 475,000 d.w.t. postwar construction program.

As you may know, our company has had a long and successful record of cooperation with the Government in joint undertakings as a result of which national defense features were built into certain of the ships of our fleet. The famed *Cimarron* type tankers constructed before World War II, some of which were later converted to baby flattops, were the first project of this type and the latest case involved the building in 1955–58 of four 37,600 d.w.t. Esso *Gettysburg* class tankers which have a service speed in excess of 18 knot. We believe that this record of Government-industry cooperation extending over the past 20 years is outstanding.

Representative VAN ZANDT. Will the gentleman yield at this point?

Mr. WINTERBOTTOM. Yes.

Representative VAN ZANDT. It may be of interest to you to know that the House Armed Services Committee today approved a Navy Department recommendation to scrap several of the Navy baby flattops which were built from the hulls of tankers initially built by the Esso people.

Mr. WINTERBOTTOM. I think they served a very good purpose.

Representative VAN ZANDT. They served a very good purpose.

Mr. WINTERBOTTOM. With respect to the Government's program for nuclear maritime propulsion, one of our group, Mr. E. L. Stewart, has been a member of the Maritime Administration Nuclear Advisory Committee since its creation in 1955. We have followed all of the developments closely and presently have one of our engineers en-

rolled in the 15 months' training course being conducted by Babcock & Wilcox under the sponsorship of the Maritime Administration and the Atomic Energy Commission.

Further, an affiliate of this company has entered into a no-cost contract with the Maritime Administration to act as an adviser to this agency on questions relating to the lubrication of nuclear and nonnuclear equipment on atomic powered vessels, to the use of petroleum or petroleum products as reactor shielding and to the use of petroleum derivatives as moderator-coolants in organic moderated reactors.

We think the Government's progress in the construction of the *Savannah* will go a long way in advancing the national interest as well as making a great contribution to the field of nuclear marine propulsion. Here, again, we see a fine example of Government effort, augmented by industry, in pioneering a project which will be mutually beneficial.

This achievement opens the ways for the next step in the marine nuclear field which in our view is the building of a nuclear-powered American-flag tanker for private ownership and operation. In this connection, however, we would like to make it clear that we are not advocating that this step be taken immediately, but that it represent an orderly development of the powerplant technology required for a successful venture.

As early as May 9, 1956, our interest in owning and operating a nuclear-powered tanker was set forth in a letter from the Esso Shipping Co. to the Maritime Administration and indeed, nominated a specific hull, then under contract, for the nuclear propulsion program if satisfactory arrangements could be concluded in the reasonably near future.

A copy of the proposal is attached to this statement for your information. It has not as yet been possible to develop a basis for our proceeding along these lines and so, due to the leadtime involved, we will complete the hull as a conventional ship.

(The letter referred to follows:)

ESSO SHIPPING CO.,
New York, N.Y., February 7, 1958.

MR. CLARENCE G. MORSE,
Administrator, Maritime Administration, U.S. Department of Commerce, General Accounting Office Building, Washington, D.C.

DEAR MR. MORSE: In accordance with your request I am submitting a suggested basis for a proposed agreement between Esso Shipping Co. and the United States of America under which a nuclear-powered tanker could be built for Esso Shipping Co.'s ownership and operation.

It is my deep conviction that a satisfactory commercial marine application of nuclear propulsion can first be attained in large tankers of a type similar to those now contracted for by our company and that the early consummation of a joint industry-Government effort along the following lines will permit our country to lead the world in the development and operation of the first nuclear-powered tanker.

In view of this company's successful record of achievement of the national defense objectives annunciated in the Merchant Marine Act of 1936 through the building of the first national defense featured tankers, and our desire to further cooperate with the Administration in the building of the first nuclear tanker, I sugegst that—

(1) The Government grant a national defense alowance to cover the difference between the cost of building a nuclear-powered tanker and a conventional tanker. This company persently has a contract with the Newport News Shipbuilding & Dry Dock Co. calling for the construction and delivery of five 47,000-

deadweight ton tankers, (Esso Design No. 786AM), three to be delivered in 1960 and two in 1961. It should be clearly understood that such an allowance is granted to compensate for the additional cost of incorporating a national defense feature in one of these ships. Under no circumstances are we prepared to consider a construction or operating subsidy.

(2) The Government and the Esso Shipping Co. jointly agree upon the design, construction and operating features of the entire nuclear propulsion project.

(3) The cost of manning and maintaining the tanker in operation will be for the account of Esso Shipping Co.

(4) The Government guarantee Esso Shipping Co. the right to purchase atomic fuel from the Government for the useful life of the reactor or of the ship, whichever is longer, on a basis approximately equalizing the cost of nuclear fuel to conventional fuel. This could readily be determined, say quarterly after the fact, by applying the weighted average of the low of Platts posting for cargo price of bunker C fuel oil over a period of 3 calendar months, plus 10 cents per barrel, to the calculated consumption based on actual operations.

However, Esso Shipping Co. is willing to consider any other means of approximately equalizing these fuel costs. Esso Shipping Co. should also have the right to purchase atomic fuel from the private producers or the Government at any lower price which may be available in the future. The Government should provide for the removal, transporting, and disposal of used fuel and atomic waste and its replacement and installation in the ship as part of the fuel cost. This assumes the use of existing shore facilities.

(5) The Government provide insurance on a nuclear-powered ship and for liabilities against nuclear hazards arising out of the design, building, ownership, or operation of the ship or the reactor, when such insurance is unavailable in the commercial market or unavailable at reasonable costs. It would appear sufficient if the Administration's proposed bill submitted to the Senate and House on January 13 in connection with insurance on the "President's peace ship" were expanded to so provide and to include any or all nuclear-powered ships built for U.S. flag operation, and/or the Price-Anderson bill be so amended to provide such insurance. If, 1 year prior to the scheduled delivery of the tanker, this insurance question has not been satisfactorily resolved, Esso Shipping Co. will have the right to withdraw from the contract. In this event Esso Shipping Co. would make every effort to utilize the reactor in a later tanker of the aforementioned five tanker building program providing such insurance is available.

(6) Since the N.S. *Savannah* is scheduled for delivery in January of 1960 and because Esso Shipping Co. is most interested in owning and operating the first nuclear-powered tanker under the American flag, it would appear that the second of the 47,000-deadweight ton tankers which is scheduled for delivery in October of 1960, is the optimum vessel for a nuclear application.

(7) The Government, acting jointly with the Esso Shipping Co. will take every needed action to obtain the necessary certificates for operation of the tanker in U.S. waters and harbors. Also, the U.S. Government will seek assurance from the Western Hemisphere governments that the tanker will be permitted to operate in their harbors.

(8) The Government permit Esso Shipping Co. employees to participate in Government operated or sponsored training programs to the extent necessary.

(9) A national defense allowance be negotiated by the Maritime Administration with Newport News Shipbuilding & Dry Dock Co., since, as earlier indicated, this company presently has a contract with that shipyard for five 47,000-deadweight ton tankers without national defense features, the second of which would be the ship proposed for nuclear propulsion.

(10) The Government accord such priorities as may be necessary to obtain all component parts for the construction and maintenance of the entire nuclear propulsion powerplant.

I trust that the above basis will meet with the approval of the Government and provide a satisfactory means of proceeding promptly with the project. It should be understood, however, that the contract covering such arrangements would necessarily require approval of the Comptroller General and the company's board, as was the case in past contracts with the Administration.

Your early consideration and reply will be greatly appreciated.

Yours very truly,

M. G. GAMBLE.

Mr. WINTERBOTTOM. This decision does not in any way lessen our deep conviction that the consummation of joint industry-Government effort earlier suggested will be in the national interest. It will be another forward step in the atoms for peace program and will give further evidence to the world of our belief in the private ownership system.

We, therefore, are anxious to reaffirm our willingness to consider the building of an additional tanker for this purpose when decision to proceed has been taken provided mutually satisfactory arrangements can be negotiated with the Government.

In brief, our proposal is to have our company pay the capital cost of the conventional tanker with the Government absorbing the additional cost arising from the nuclear power application. Fuel costs would be apportioned on approximately the same basis.

Insurance would be bought from the Government to the extent not obtainable from commercial sources on a reasonable basis. These are the main points, although we recognize that such an important and complex relationship will require intensive study and detailed negotiation.

Further, we recognize that despite Government assistance in such a project the problems and costs of owning and operating a nuclear-powered tanker may very well be greater than those associated with the conventional tankers.

Why, then, are we willing to accept this potentially greater and, at present, not wholly predictable burden? First, because of our belief that the national interest requires the United States to stay in the forefront of peaceful applications of nuclear energy. Second, our desire to again cooperate with the Government in embodying national defense features in the ships of our fleet. Third, as a major producer and distributor of petroleum in the United States, it is our desire to contribute in anyway we can to significant developments in the tanker transportation field.

I very much appreciate this opportunity to meet with this distinguished committee and after making it clear that I am not a technical man, will be happy to answer to the best of my ability, any questions you may have.

Chairman ANDERSON. I notice the proposal starts off with a Government grant to cover the difference between the cost of building a nuclear-powered tanker and a conventional tanker. Would that be a grant in full—that is, a 100 percent grant in the difference of cost?

There have been some suggestions that the Government might take 75 to 80 percent of the cost of the powerplant. Do you believe that in this ship they should assume the entire cost between the conventional and the nuclear?

Mr. WINTERBOTTOM. The proposal we make, Mr. Chairman, is that the Government pay all the costs over and above what a conventional tanker would cost at the time we make the deal.

Chairman ANDERSON. What incentive would there be for you to keep that cost down as much as possible?

Mr. WINTERBOTTOM. The cost of the application of the nuclear propulsion would be more or less in full control of the Government.

Chairman ANDERSON. But if the Government was going to take all the cost between the conventional plant and the nuclear-powered

plant, what incentive would there be to your company to keep the cost as low as possible?

Mr. WINTERBOTTOM. I don't think there would be any incentive.

Chairman ANDERSON. You also suggest that the Government guarantee the Esso Shipping Co. the right to purchase atomic fuel from the Government for the useful life of the reactor or of the ship whichever is longer, on the basis of approximately equalizing the cost of nuclear fuel to conventional fuel.

What incentive would there be for your company to design the most economical type of reactor or do as they have done in the Shippingport plant where they have steadily tried to improve the process?

Mr. WINTERBOTTOM. Mr. Stewart, would you like to answer that?

Mr. STEWART. I think I can answer that.

We have been endeavoring for several years to reduce the cost of fuel elements. For several years we have been working very closely with several of the manufacturers of nuclear propulsion powerplants and our objective has been to reduce the first cost, not only of the reactor itself but of the fuel elements.

We have in the past year been able to reduce that cost in the case of the pressurized water reactor very appreciably. We have been working very actively on that reduction. When it comes to an incentive, I believe the way we work with the Government provides that. Everything is taken out on a competitive bidding basis and approved by the Government before we ever enter into it. We actually get none of the money directly. It is paid directly to the shipyard and is absolutely under the control of the comptrollers and everyone connected with it from the Government angle.

Chairman ANDERSON. You do not believe there needs to be any incentive in this?

Mr. STEWART. I do not believe there needs to be any other incentive because it is controlled and we want the cheapest price ourselves.

Chairman ANDERSON. Mr. McCone, in his testimony, suggested that on the construction of nuclear plants, if a grant were given, it might not exceed 50 percent of the total cost of the nuclear plant. How would that work out in connection with this? You would need more than that, would you not?

Mr. STEWART. Yes, we would under this basis.

Chairman ANDERSON. It seems to me that his idea might have been that the company should have some incentive to do a little planning and economizing itself and not just know that no matter what it spent, the Government would take it.

Mr. STEWART. I think it is our past performance that would show that we are always trying to reduce the cost to the Government. That has been historical and we are still going to continue that in anything we do in an endeavor with the Government.

In all cases we have the lowest fuel consumption now of any marine steam job commercially, so we are creating this condition all the time in our studies.

Chairman ANDERSON. I am very anxious to see a nuclear tanker built. I think that is one of the great possibilities. You may know I have been advocating it for some time. If you want to get it done, why are you not willing to take just a little bit of the risk or have a chance to profit to a small degree by your own activities?

Why do you want the Government to take it all? This is the American enterprise system we are talking about.

Mr. STEWART. I think in defining the parameters of what the difference would be, there is very little structural change that would be necessary. It is purely in the nuclear powerplant and modifications of the present turbines.

Chairman ANDERSON. You only want the Government to guarantee you that whatever the extra costs, no matter what it may be, the Government takes it all. Then, when you operate it, no matter what the costs, the Government takes it all.

Mr. STEWART. No.

Chairman ANDERSON. Yes, if I can read it correctly. Did I not read it correctly?

Mr. STEWART. Not the fuel cost.

Chairman ANDERSON. No, whatever extra it is over conventional fuel, the Government takes the whole responsibility.

Mr. WINTERBOTTOM. If there is any extra cost.

Chairman ANDERSON. Do you not have any extra load capacity?

Mr. STEWART. Yes.

Chairman ANDERSON. Where does the Government get credit for that? The Government would have the basis of approximately equalizing the cost of nuclear fuel to conventional fuel?

Mr. STEWART. That is right.

Chairman ANDERSON. Should there not be some comparison to operating cost? If you carried a greater load would you not have some saving?

Mr. STEWART. We would be assuming quite a responsibility in operating the ship. There would be increased costs in that.

Chairman ANDERSON. What responsibility would you assume?

Mr. STEWART. In the manning. That would be an increased cost. In the repair and maintenance of the nuclear powerplant.

Chairman ANDERSON. In repair and maintenance, does the *Nautilus* operate comparably with an ordinary coal or oil-fired vessel?

Mr. STEWART. I would be of the opinion that the cost is higher.

Chairman ANDERSON. I would, too. Not on the question of turnaround, for example?

Mr. STEWART. No.

Chairman ANDERSON. If you can operate steadily for 90,000 miles, that is a little better than an ordinary ship, would you not think?

Mr. STEWART. That is an extraordinary condition.

Chairman ANDERSON. Might that not be a saving to you? But you don't want the Government to have any credit for that?

Mr. STEWART. That is probably some of the balance that would occur in this increased operational cost to us. That is, any saving that is incurred in the fuel costs.

Mr. WINTERBOTTOM. I think the answer to your question, Mr. Anderson, is that our whole interest in pursuing this is to develop cheaper transportation if it is possible.

Chairman ANDERSON. Yes, but as I understand it, your interest does not rise above the fact that this might cost as much as $100 more. You are not willing to spend anything more. You are going to have the Government pay all the costs.

Mr. WINTERBOTTOM. In the way of capital costs.

Chairman ANDERSON. And all the operating costs as far as fuel is concerned.

Mr. WINTERBOTTOM. Just as far as fuel is concerned.

Chairman ANDERSON. If there are any economies because of the fact that you can carry a greater cargo, you don't want the Government to have that.

Mr. WINTERBOTTOM. I think in the final accounting, we will work out the differential of costs and there would be some consideration given to that.

Chairman ANDERSON. Where is there anything about the final accounting in the letter?

Mr. WINTERBOTTOM. This is merely a proposal that we have made. We have never gotten down to discussing it.

Chairman ANDERSON. The Government has to accept or reject your proposal. That is what I am looking at.

Mr. WINTERBOTTOM. I think we referred to it. It is a complex question. We would negotiate it.

Chairman ANDERSON. You want the Government to take the insurance, do you not?

Mr. WINTERBOTTOM. Yes, sir; over and above what we can arrange.

Chairman ANDERSON. What hazard would you be taking?

Mr. STEWART. In regard to the fuel, I think it stipulates in the original letter that it was to be the difference as determined by the facts between the cost of nuclear fuel and fuel oil.

Chairman ANDERSON. Yes, I just read that. On the basis of equalizing the cost of nuclear fuel to conventional fuel. If there are some operating advantages why should the Government not get those?

Mr. STEWART. I think there would be a determination of the cost of the fuel according to the facts. That is the next part of the sentence, I believe.

Chairman ANDERSON. I suppose so. I am not able to understand the language, probably.

This could readily be determined, say, quarterly after the fact by applying the weighted average of the low of Platts posting for cargo price of bunker C fuel oil over a period of 3 calendar months, plus 10 cents per barrel, to the calculated consumption based on actual operations.

I would not know what bunker C fuel should have as to Platts. I do not even know Platts. If you are interested in this, I am simply saying that Mr. McCone suggested the other day that possibly there ought to be some incentive in the company to do the lowest price job it could.

If it had just a fraction of its own money invested it would have that incentive. If I am wrong, you say so, but I think you have carefully guarded to see that there would be no hazard whatever in the operation of these. Is that correct?

Mr. STEWART. That is true. That is the fact.

Representative HOLIFIELD. Mr. Chairman, I just want to explore the approximate price between the 47,000 DWT tanker now under contract with the Newport News Shipbuilding & Dry Dock Co. and what the estimate is per tanker for a nuclear type vessel.

You must have some figures on that even though they are speculative.

Mr. STEWART. The contract price of that ship was $13.5 million, and it is subject to escalation that could possibly amount to about another million and a half. That would be the finished cost. The power in that vessel would be almost similar to the power in the various projects that are being discussed now, the 22,000 shaft horsepower. The price of that, as a nuclear power supply—that is, the reactor and all of the equipment, the tools for maintenance and erection and the inspection, supervision, and certificates—would be about $9 to $9½ million, including the fuel element cost.

Representative HOLIFIELD. Is that the difference?

Mr. STEWART. That is the cost of the nonerected, noninstalled nuclear power supply. That is just as delivered from the manufacturer.

Representative HOLIFIELD. The nuclear cost?

Mr. STEWART. That's right.

Representative HOSMER. What is the net nuclear cost when you subtract whatever conventional machinery you would put in?

Mr. STEWART. In the installation costs where the difference would be figured, that would be about $3 to $3½ million.

Representative HOLIFIELD. In addition to the $9 million?

Mr. STEWART. Yes, sir.

Representative HOLIFIELD. That gives us a total of about $13 million for the nuclear cost.

Mr. STEWART. Installed and with credits that are allowed.

Representative HOLIFIELD. In your $13 million contract price, what do you have in that as your conventional propulsion cost? Are the engines figured extra?

Mr. STEWART. No. They are in that cost.

Representative HOLIFIELD. How much are they?

Mr. STEWART. That is hard to tell because there is an entire plant, with shafting and all, that would be in this. What I figured is the difference between the cost of the turbines in the installation price.

Representative HOLIFIELD. That gives me the net figure of $13 million.

Mr. STEWART. Thirteen to 13½; yes, sir.

Representative HOLIFIELD. Yes. You would expect the Government to carry that?

Mr. STEWART. That is the amount.

Representative HOLIFIELD. On your $13.5 million, you are building these under the Merchant Marine Act?

Mr. STEWART. No, sir.

Representative HOLIFIELD. Your $13.5 million is complete commercial and private funds?

Mr. STEWART. Yes, sir.

Representative HOLIFIELD. There are no Government funds in that as there are in the Merchant Marine Act for shipbuilding?

Mr. STEWART. That's right.

Representative HOLIFIELD. This would mean a total to the Government of about $13 million for each tanker as the original cost, and then the differential in the cost of operation from the standpoint of fuel and insurance and reprocessing.

I notice you also have in your letter of transmittal that the Government should provide for the removal, transporting, and disposal of used fuel and atomic waste, and so forth. This assumes the use of exist-

ing shore facilities, so it is really not quite clear exactly how much it would be, but it would amount to quite a bit.

Mr. STEWART. The capital cost would be about that amount. These other operations are not possible to do as a private party at this moment, so we don't know what that would cost us.

Representative HOLIFIELD. It is not possible from the standpoint of the facilities that are available, but it might be from the aspect of the charge of a facility.

Mr. STEWART. Yes, sir.

Representative VAN ZANDT. What is the status of your proposal with the Maritime Administration?

Mr. WINTERBOTTOM. I just recently talked with Mr. Morse and he feels that there is no point in our further discussing this matter with him until he has enabling legislation.

Representative VAN ZANDT. In other words, it is up to the Congress to enact enabling legislation?

Mr. WINTERBOTTOM. That is as I understand it. We are in touch with him regularly.

Representative HOSMER. Mr. Winterbottom, you are vice president in charge of the marine department of Esso.

Mr. WINTERBOTTOM. In Esso Standard the directors and officers are not in charge of departments. We have a general responsibility.

Representative HOSMER. You are down here. Why?

Mr. WINTERBOTTOM. As the contact director of the marine department. The general manager of the marine department is sitting there.

Representative HOSMER. I did not understand who this other gentleman is with you.

Mr. WINTERBOTTOM. Mr. Stewart is our naval architect and chief constructor and in charge of the construction and maintenance department of the marine department.

Representative HOSMER. The reason I asked Mr. Holifield to yield awhile ago is that I got lost in Mr. Stewart's calculations here. Your price tag for these tankers you are buying up here is how much—$13½ million, plus a possible $1½ million extra?

Mr. STEWART. That's right.

Representative HOSMER. What is the price tag of a nuclear-powered job with the same hull?

Mr. STEWART. The addition would be $13 to $13½ million.

Representative HOSMER. Twice as much?

Mr. STEWART. Yes, sir.

Representative HOSMER. Mr. Winterbottom, you were being questioned here by Senator Anderson a moment ago. I never did understand anything but the fact that you wanted the Government to put up this $13½ million extra, is that right?

Mr. WINTERBOTTOM. That is correct.

Representative HOSMER. And plus any operating cost?

Mr. WINTERBOTTOM. Any excess cost of the fuel. The value of the fuel is beyond our control, as you understand. It does not move in relation to any other fuel.

Representative HOSMER. That is right. Your bunker oil is relatively cheap fuel, isn't it?

Mr. WINTERBOTTOM. Yes.

Representative HOSMER. Just where or what are the taxpayers of the United States going to get out of putting up this $13½ million?

Mr. WINTERBOTTOM. Ultimately we hope to have a very definite advance in reducing the cost of transportation.

Representative HOSMER. Who is going to get the advantage of that, the stockholders or the taxpayers?

Mr. WINTERBOTTOM. The consumers of all the products that are transported. Not only petroleum products.

Representative HOSMER. Has that been the history in the past?

Mr. WINTERBOTTOM. Yes, sir.

Representative HOSMER. Are you familiar with the Isbrandtsen operation?

Mr. WINTERBOTTOM. I saw the proposal and we have been talking with the Maryland Dry Dock people along the same lines.

Representative HOSMER. I ask you if you are familiar with the Isbrandtsen operation.

Mr. WINTERBOTTOM. No.

Representative HOSMER. You do not know whether they have had any experience operating tankers or not other than this one they are talking about?

Mr. WINTERBOTTOM. I would say they are a good operator, if that is what you mean.

Representative HOSMER. Of tankers?

Mr. WINTERBOTTOM. They are experienced operators, yes.

Representative HOSMER. Are you familiar with this proposal that they came up here with that cut out a section of the after tanker and inserted a reactor?

Mr. WINTERBOTTOM. In their particular proposal, I did not know about it until it was presented here.

Representative HOSMER. Is it a practical one?

Mr. WINTERBOTTOM. It is a proposal that we will certainly look at when we get further along on this. We believe up to the present that it is more expensive.

Representative HOSMER. It is more expensive when you bring the ship in and cut it in half. You have been complaining because they will not take action on your proposal on one of these three new tankers. So you are going to build a conventional one. Could it reasonably be subject to the same sectionalizing operation?

Mr. WINTERBOTTOM. I think it could be if we all agreed that is as economical a way to accomplish what we are after.

Representative HOSMER. You got pretty high pressure and temperature steam in those powerplants?

Mr. WINTERBOTTOM. It would be the same that we would propose in the nuclear powerplant.

Representative HOSMER. What is it?

Mr. STEWART. We would have to modify the turbines, sir. We have 858–850 in our present jobs. We would have to modify the rotors and turbines. It can be done.

Representative HOSMER. You would contemplate lower temperature and pressure steam for the nuclear plant?

Mr. STEWART. We would have to. If we could at some time increase that, we would change the blading.

Representative HOSMER. You could not use the sectionalizing application without changing the whole engineroom of the tanker.

Mr. STEWART. No. We could use it exactly like that.

Representative HOSMER. You would have to take out your turbine?

Mr. STEWART. No, sir.

Representative HOSMER. You could just modify it?

Mr. STEWART. We would contemplate that the reactor would go into the aftermost tank. We would have to build a control house directly above it as a supplementary house to the poop.

Representative HOSMER. I understand that. I am talking about the temperature and pressure of the steam that comes out of your reactor in relation to what your turbines require.

Mr. STEWART. That would mean a modification of the rotors and turbines. We could change for the steam conditions quite readily.

Representative HOSMER. That is all.

Representative HOLIFIELD. Thank you, gentlemen.

Mr. WINTERBOTTOM. Thank you, sir.

Representative HOLIFIELD. The next witness is Mr. Philip Sporn of the American Electric Power Service Corp. of New York City.

STATEMENT OF PHILIP SPORN, PRESIDENT, AMERICAN ELECTRIC POWER CO., NEW YORK, N.Y.

Mr. SPORN. Thank you, sir.

Representative HOLIFIELD. Mr. Sporn, we are running late, and we have two more witnesses after you, and it is embarrassing for me to ask you if you would summarize your statement.

Mr. SPORN. I will try, Mr. Holifield.

Representative HOLIFIELD. If you can introduce it for the record in complete form and summarize it, we will appreciate it.

Mr. SPORN. Yes, sir.

I want to express my appreciation for the invitation to appear before your committee to testify in these hearings. As chairman of the research and development committee of East Central Nuclear Group, Inc. (ECNG), I shall first make a very brief statement about the project which has been proposed and is being carried out by ECNG and the Florida West Coast Nuclear Group (FWCNG).

For the rest, I appear as president of American Electric Power Co. and will discuss item 1 of the committee's suggested list of topics.

As to the ECNG-FWCNG project, I am happy to report that all the contractual relationships involved have by now been pretty well worked out. The contract between ECNG-FWCNG and the Atomic Energy Commission, the contract among the member companies of ECNG, and the contract between ECNG and FWCNG are all in final form and their execution should take place in the next few days.

As a matter of fact, we expect the contract with the Commission to be executed on the 26th. But the technical work on the project which started March 1, 1958, has not been held up while contract negotiations were proceeding. In fact, since last March the work has been progressing according to plan in both engineering studies and experimental investigation.

Engineering design studies are being conducted by General Nuclear Engineering Corp. (GNEC), and American Electric Power Service

Corp. (AEPS). At GNEC the nuclear reactor design is being explored while AEPS is investigating the plant equipment and layout in collaboration with GNEC.

Approximately 20 engineers and scientists are working at GNEC and another 20 at AEPS are engaged in these design studies. Other men at GNEC are employed in the experimental laboratory work.

With respect to the laboratory work, there are three major test loops for determination of corrosion and heat transfer characteristics scheduled to start operation within the month. Other test facilities are in the planning or construction stages.

The successful fabrication of welded zirconium pressure tubing by techniques proposed by the manufacturer for the production of commercial lots for use in reactors—still to be subjected to stringent testing—is certainly an encouraging step forward. Negotiations are underway for the in-pile testing of fuel bundles and beryllium cladding material.

Total expenses incurred to date are approximately $670,000 and during the year 1959 we expect that the expenditures will amount to over $2.8 million. We believe the project, as approved by this committee and the Congress last year, is moving ahead at a very good pace.

I want to turn now to item 1 on your list of suggested topics, "The Government's power reactor policies and programs, both domestic and foreign."

On the whole, I think the report of the Atomic Energy Commission's ad hoc committee is excellent. Among the objectives described in the report, however, I have reservations about the thesis that it is necessary to reduce the cost of nuclear power in this country to a point competitive with power from fossil fuels, in certain areas, within 10 years.

While this would be a splendid achievement, it is not, in my view, an urgent necessity in the same sense that many of us may feel, for example, an urgent need to assure the elimination of any lag in the field of guided missiles. Nor do I see the urgency to achieve competitive nuclear power costs in less than 10 years in friendly foreign nations.

My reasons for the foregoing views were spelled out more fully in comment to the committee on your staff's paper of August last, so I need not repeat them now. At the same time, I believe in a vigorous program for development of atomic power as this committee knows from our work in the ECNG–FWCNG and other projects.

I would also like to see among the several objectives of our program the orientation of atomic power development as soon as possible and as completely as possible within the institutional framework used for the development of conventional energy resources.

In my judgment the most efficient development and most beneficial applications of atomic energy can result only from the voluntary cooperation of equipment manufacturers, the electric power systems—public and private—and other related industries in the absence of the special restrictions and special forms of assistance which are necessary during the present transition period.

This objective is of extreme importance. I do not believe the sound commercial exploitation of atomic energy will otherwise be achieved,

either in the case of public or private power systems or other industries.

Finally, especially over the next dozen years or so, I believe research and development per se should be encouraged and their importance and value recognized regardless of whether or not a particular line of research leads to the construction of a reactor plant.

Of course, in many cases, prototype and even demonstration plants may be indicated, but a research and developmental program can be highly successful without leading to either.

I hope also that out of the work of the ad hoc committee and of this committee there will come forth a statement of objectives, policy, and program agreed to by the Joint Committee and the Commission which, while looking considerably ahead, will still be sufficiently flexible to be modified and reshaped as progress in the research and development program indicates new channels of approach or a new distribution of emphasis.

In my remaining time I want to speak of the vital importance of our national policy on atomic development when viewed against the background of the overall energy supply problems of the country in the next several decades. It seems to me that it might be helpful to place before the committee my outlook respecting future requirements for energy and future supplies.

I should say, primarily, that in this projection—and having in mind the technological and engineering-economic problems of atomic power—I have taken what I believe to be a very optimistic view of nuclear power development in the rest of this century. Thus, my estimate for the year 1975 assumes 100 nuclear plants with an aggregate capacity of 20 million kilowatts, and for the year 2000 assumes that nuclear power will become generally competitive well before that date and will account for about 75 percent of the total increase in electric generation in the period between 1975 and 2000.

I have no doubt that there can be substantial differences of opinion about my outlook and the assumptions underlying it. There can be differences in assumptions about technological change. It is possible to imagine changing technology about which we now know very little.

For example, it is possible to assume—although I am not prepared to make that assumption—that the gasoline-driven motor vehicle will be replaced by a battery-driven motor vehicle which will receive its charge from nuclear-generated electricity.

Numerous other processes which require oil or coal or gas—for example, the home heating market—may possibly become almost entirely electric, so that nuclear-generated electricity could substitute for the oil, gas, and coal that would otherwise be used for space heating.

Such developments could certainly affect future prospects substantially. Nevertheless, the projections which I have made represent my best judgment in the light of present technology and knowledge.

In my projections, to facilitate comparisons, I have converted all the forms of energy to a common unit—tons of bituminous coal equivalent.

I start with a projection of 2,000 billion kilowatt-hours as this country's electric requirements in 1975—or three times that of 1957.

This represents a fuel requirement equivalent to 700 million tons of coal in 1975 as compared with less than 300 million tons coal equivalent in 1957.

Although I have spent a great deal of time studying the probable electric energy generation in the year 1975, I must express caution that the projection of 2,000 billion kilowatt-hours as the country's requirement for that year is obviously one that cannot be made with any fine precision.

I think it is a reasonable projection of the probable order of magnitude. There have been some slightly more optimistic and other considerably less optimistic projections. In the trebling of electric energy generation between 1957 and 1975 to reach the total of 2 trillion kilowatt-hours, I have estimated that 150 billion kilowatt-hour, or 7.5 percent will be generated by nuclear power.

If nuclear power had no more place in our energy picture than to provide 7.5 percent of the total electrical energy requirements, or less than 2 percent of our total energy requirements in 1975—which total energy requirements I estimate at over 2,700 million tons of coal equivalent—there really would be little justification for all the activity and all the national effort that is being given to this atomic program.

The justification for what we are doing is the belief—which in my judgment is sound—that as the country's future need for energy expands, atomic power will be able, on an economic basis, to assume the burden that the other sources of energy will be then unable to carry effectively.

For some appreciation of what this may involve, I have made a projection beyond 1975. I have attempted to do this, and I have done so with much hesitation, with particular regard for the fallibility of projections as far ahead in the future as 40 years or more.

In the case of electric energy—optimistic as I am about its increasingly effective utilization—I feel that there are factors of saturation that we are only dimly aware of at the present time which may arrest the present rate of growth.

Nevertheless, I have estimated for the year 2000 a total generation of 6,000 billion kilowatt-hours. This is nearly 10 times the electric energy generation of 1957. It may eventually prove to be in error by a substantial margin, more likely on the high than the low side.

I have made this projection, however, not for precision but to examine, on the basis of an order of magnitude that can reasonably be anticipated, the fundamental purpose for our atomic program.

Assuming these projected requirements, I estimate that in the year 2000, nearly 40 percent of this total will still be generated by coal, a small amount by fuel oil and by gas, some 350 billion kilowatt-hours by hydro—this is not quite three times the amount we generated hydraulically in 1957—and the largest percentage, not quite 55 percent by nuclear fuel.

For 1975, I estimate a possible consumption of 475 million tons of coal and 50 million tons of coal equivalent of nuclear power for electric energy generation. For the year 2000, I estimate a relatively small increase over 1975 in the coal portion to 600 million tons, but for nuclear power more than a seventeenfold increase to the equivalent of more than 850 million tons of coal.

But more significant is total energy consumption for all purposes in the United States. The interesting thing to point out here is that while electric energy kilowatt-hours increased almost fifteenfold between 1920 and 1957—from 39 billion to 631 billion kilowatt-hours—and the total energy consumed for electric generation increased only fourfold, from 77 million to 293 million tons of coal equivalent, the total energy used in the United States little more than doubled, from 755 million to 1,607 million tons of coal equivalent.

Parenthetically, energy consumed for electric generation increased in this relatively low proportion, as compared with kilowatt-hours produced, because of increased generating efficiencies in that interval. The best projection that I feel I can make for 1975 is an increase in total energy from 1,607 million tons of coal equivalent in 1957 to a figure that would be about 70 percent greater, 2,750 million tons; and I estimate the total energy requirement in the year 2000 as equivalent to 4 billion tons of coal.

This is an increase of close to 50 percent in the 25-year interval 1975–2000.

Yet, despite the optimistic projection of electric energy use and the assumption that nuclear power will account for over 75 percent of the increase in electric energy generation between 1975 and 2000, the part of the total energy requirements of all kinds that is likely to be satisfied by nuclear energy in that year is only slightly over 20 percent, that is, 850 million tons of coal equivalent out of 4 billion tons.

This still leaves almost 80 percent of our total energy requirements to be supplied by conventional sources. Of the 80 percent, approximately 20 will still go to generate electric power; the remaining 60 for all other energy work.

Having in mind that the projections I have made are only to be regarded as an order of magnitude, it seems to me that one certain and inescapable conclusion can be drawn which is directly pertinent to the program we are attempting to develop at the present time.

It is clear that our total energy requirements in the year 2000 and in the intervening period will necessarily require very large amounts of fossil fuel. I believe there is grave danger—and I cannot overemphasize the vital importance of avoiding that danger—that so great an emphasis will be placed on atomic power development that we will tend to forget the essentiality of fostering the continued development of an adequate supply of coal, oil, and gas for the long period during which atomic energy will only gradually assume an increasing part of our total energy burden.

Even allowing for a very wide range of error in projections, the trends and tendencies they reveal, the need to provide until the year 2000 and even beyond increasing quantities of fossil fuels, especially coal and liquid fuel, the likelihood that nuclear power will by then be able to supply a very large quantity but still only a limited share of our total energy requirements, remain unchanged.

It is against the background of an overall outlook of our total energy requirements such as this that we must consider our atomic program if we are to provide an adequate supply of total energy in its proper forms. In our concern for the long-term promise of nuclear energy we cannot permit ourselves to lose perspective.

We cannot forget the continuing importance of our fossil fuels. We must be certain that they will be able and will continue to provide for some time to come the far larger share of our total energy needs that nuclear power will not be able to satisfy even under the most favorable conditions.

These are the conditions that I have assumed.

Representative HOLIFIELD. Thank you very much, Mr. Sporn, for your statement.

Chairman ANDERSON. I notice on page 13 you refer to the enormous demands for coal. There was some discussion of the fact that the coal people or representatives of coal areas seemed to be worried about the atomic power program a year or two ago.

On this basis we do not have to worry that atomic energy is going to take the place of coal. We have to worry about the need of the development of coal resources.

Mr. SPORN. I think, Senator, that coal has a terrific and most important part to play in the history and destiny of this country for the next 25 to 35 to 40 years. I do not know what our coal people were concerned with, but I am inclined to the judgment that they may have been concerned with the status of their present condition rather than their future euphoria that is ahead.

Chairman ANDERSON. I am not complaining about what they did or did not do. I am merely trying to say as far as the coal industry is concerned, atomic energy is not causing any great worry at the present time.

Mr. SPORN. I have tried to tell the coal industry, Senator, that there is a great future ahead for them.

Representative VAN ZANDT. As one who represents a district where we dig a lot of bituminous coal, I must say that your statement here is very encouraging.

Speaking for the coal industry, they are not worried about research and development in the field of atomic power. But they are concerned about the Government subsidizing the competitors. I think that was the concern that they expressed here some few years ago.

I would take it from your statement that you would encourage both the Government as well as the industry to spend a little more money in the field of research as far as coal is concerned?

Mr. SPORN. I think, Congressman Van Zandt, there are many things that need to be done but that surely would be a very excellent thing to do among many others. We are going to need coal in the economy and in the defense of this country for a long time to come.

Representative VAN ZANDT. I was interested in your statement that atomic energy will produce 20 percent of the energy needed in the year 2000. Some years ago we were given a figure of 10 percent.

Mr. SPORN. You will recall, Congressman, I said that there could be differences of opinion on this estimate and I would be inclined to think that my estimate is rather overoptimistic than on the pessimistic side.

I purposely trended all my thinking in that direction so as to see what part of our total energy picture atomic energy could fill in, in the year 2000. The answer that I arrived at is not over 20 percent of our total energy picture.

Representative VAN ZANDT. That is all, Mr. Chairman.

Mr. SPORN. That is giving atomic energy in the year 2000 the equivalent of 855 million tons of coal and that is more than twice as much coal as was mined in the United States in the year 1958.

Chairman ANDERSON. Are there additional questions?

Representative HOSMER. May I ask Mr. Sporn this question: I cannot conclude exactly what you would recommend as to the Government's role in spurring atomic development. Are you familiar with Mr. McCone's testimony that he gave a few days ago?

Mr. SPORN. Yes, sir.

Representative HOSMER. Would you say that in relation to the projections you have given to the committee today that what he recommends is a little more than we should be doing right now, a little less, or about right?

Mr. SPORN. I think that the program that the Commission is recommending as near as I can see, is not very much different from the program that the committee itself is proposing and is about of the right order. I think it is a very comprehensive program.

So far as I know it is the most comprehensive program of any being followed today by any nation in the world and I do not exclude the Russians. I am not sure that I am in entire agreement as to the absolute necessity of setting a finite time. I think we could put in a little more flexibility in it.

One of the things I believe we ought to take a look at continually is this: In projecting our atomic program, I think we ought never to project it except against a background of our total energy needs, present and prospective. We have some information. I put together some information before I came to testify here this afternoon.

The only good study that we have is almost 10 years old—the Paley report which was a study of our total energy requirement. That only attempted to look ahead 25 years. One of the things I believe we might do is to get some new information as to what our real energy requirements are going to be, let us say 25, 30, 40 years ahead.

That is not going to be an easy matter but I would think an indispensable matter for any one engaged in projecting an atomic program, which is a program to try to take care of our long term rather than our immediate energy requirements.

I think we ought to have some very good pictures of what those long-term requirements are going to be, in what parts of the economy they are going to be and what particular parts of our total energy resources can fulfill them. We will then be in much better shape to continue to project our atomic program intelligently and in the best interests of the country.

Representative HOSMER. In other words, we should have a yardstick that reaches out at least 36 years in relation to our energy requirements by which we can measure the adequacies or inadequacies of our present program and we do not happen to have that yardstick right now; is that right?

Mr. SPORN. I think we need that kind of yardstick. I think it needs to be reviewed and revised from time to time because as a long-time projection it is bound to be in error when it is made. I do not think it is possible, without having that before you all the time, to do a really first rate intelligent job.

Representative HOSMER. I am quite inclined to agree with you.

Chairman ANDERSON. I am happy to say that some of us have been suggesting that maybe we should try to bring the Paley figures up to date along with certain other figures and take a new look at them. A great many of those figures have been shown to be a little bit conservative because of the terrific population growth we have had and maybe we should compare it again.

Mr. SPORN. I have made some more optimistic projections here, Senator, than the Paley report.

Chairman ANDERSON. These are good and they are appreciated very much, Mr. Sporn.

Mr. SPORN. Thank you very much.

Chairman ANDERSON. Mr. Kasschau.

Mr. KASSCHAU. Thank you, Mr. Chairman.

Chairman ANDERSON. I want to say the same thing that Mr. Holifield said. Any time you want to summarize or skip a little paragraph we will be glad to have you do so. At the same time we will be glad to have you read it all.

STATEMENT OF KENNETH KASSCHAU, MANAGER, NUCLEAR POWER ENGINEERING, ALCO PRODUCTS, INC.

Mr. KASSCHAU. Thank you. I shall try to conserve on the committee's time.

While Mr. Sporn was speaking I did a little further editing and got it in shorter form. For the record my name is Kenneth Kasschau, and I am manager of nuclear power engineering department at ALCO Products in Schenectady. We are very pleased to have this opportunity to appear this afternoon because we are quite active in the program and have a long-standing interest in the program and meetings of this nature in the development of the long-range policy.

I should like to express ALCO's appreciation for this opportunity to appear before the Joint Committee. We are very active and, therefore, vitally interested in the atomic energy program. Because of this, we are always happy to meet with the members of the Committee and others interested in the unfolding policy and program for this vital field of technical endeavor.

I am sure that some of you are familiar with ALCO's role in atomic energy, but I should like to take a moment to recap our position briefly. We have elected to stay with small powerplants, which we define as under 20–25 megawatts of electricity. We have chosen this because it fits in with our central role as manufacturers of packaged powerplants in the form of locomotives and small stationary and marine power units. This experience, plus our established process equipment manufacturing activity, led us to establish our nuclear power engineering department nearly 5 years ago.

The first step taken by this part of our organization was the construction and operation of the APPR–1 which, as you know, we completed quite successfully a little ahead of schedule a year ago last July. We are still operating the APPR–1 under a contract, which, in addition to outright operation, includes participation in the training of military personnel and a substantial research and development program on various aspects of plant design and operation. We also have completed the design of APPR–1A for Fort Greely, Alaska,

and we are now manufacturing most of the primary equipment for this second Army powerplant, with deliveries of our equipment starting in less than 6 weeks.

Late last month we received a contract for the design, construction and preliminary operation of a truly packaged nuclear powerplant. We are intensely proud of this unit because it is a plant the size of APPR–1, but its weight has been reduced more than 80 percent. We have actually designed the unit to be placed on skids, which can be tractor drawn over icecaps, or other remote regions, and erected within 60 days. It represents a very considerable challenge, because again the contract is a fixed-price contract and because the schedule calls for completion in less than 16 months. We see no reason to doubt that we will deliver again on schedule—the 20th of May 1960.

From the above brief résumé, I believe it is clear that ALCO has concentrated its major activity in service to the military. This was our initial objective in the APPR–1 competition. It is our current major objective and it will continue so for some time to come. We feel that, although economics alone do not justify even the military applications, we are making progress in economics and there is a job to be done that only atomic energy can achieve.

We are pushing the pressurized-water type and urge its adoption in these applications because we know it can do a job now that needs to be done immediately. While other systems are being developed which will ultimately surpass the PWR type of plant, the simplicity and stability of the pressurized water system is unmatched today, and further, the technology of the plant is the only one that can be considered reasonably well developed.

I have no doubt that some of these improved systems will one day make our current skid-mounted unit look like a covered wagon train, but the covered wagon did a pretty good job in its day. We have to learn as we grow, and this has been demonstrated many times over in the experience of all of us. To put a slightly different twist on this, I am sure that we wouldn't have done very well in World War II if we had waited for supersonic aircraft to become available. Actually, while it may not be obvious, I think it is quite true that if we had had such a plane, we wouldn't really have been able to use it, because we would not have developed the techniques which we did by growing progressively.

The above discussion leads quite naturally into the first of two points which I wish to make this afternoon. This is not new, but I raise it without apologizing for being repetitious. The point is that the small reactor serves best the development of nuclear technology for all plants, be they large or small. I know this is an old saw, as I indicated before, but there is one difference in my mentioning this conviction today—I now have nearly 2 years of operating experience behind me and can point to many specific items to support this contention. With your permission, I should like to describe one of these now.

Large areas of unknowns during the design of APPR–1 were integrated problems of primary-system corrosion, activity accumulation, water purification and system decontamination. We did not know, for example, the effect of surface roughness on corrosion rates. Had we known that, we would not have known what this would indicate,

so far as radioactivity buildup was concerned. Even if we had known the answer to this problem, we still would have been far from certain as to the rate at which we could remove it in the purification system. Going further, with all of that, we still would not have known how fast this activity would accumulate in various parts of the system. All of this information was needed before we could know how serious an activity problem would arise when undertaking maintenance of a component, such as the steam generator.

We did the best we could in analyzing each of the above problems and engineered the best system that we could in the time that was available. There was neither time nor money to establish large research programs on each of the above variables, so we used engineering judgment liberally. As of today, we have nearly 2 years of operating experience, which shows that some of our judgment was good and some of it was bad, as is to be expected in any problem as complex as this one. The important thing is that with reasonable care we did engineer a system which was operable and have developed actual experience to show the net effect of all these variables. Further, with them at hand, for a modest expenditure we have developed a quite successful decontamination method which is being used as a basis for similar systems on the very large plants.

I could enumerate many other areas where we have learned on the small plants. The significant fact is that this has been done in about half the time that it took to develop the PWR, and at a total cost to date—including the APPR construction cost—of about one-tenth of the cost of research and development alone on the big plant.

Now, I don't mean to say that we have learned all that has been learned on that big program, but I do insist that what we have learned has been truly applicable. If this were not so, it would certainly be hard to understand why we have a continuous stream of visitors in Schenectady from the people concerned with these very much larger plants.

It is not possible, I agree, to develop all of the information which is necessary for the construction of major plants. I believe, however, that we can develop substantially all the information which is vitally needed to do an intelligent job of designing a big plant, by first designing and operating small plants. We can do it quicker and cheaper, because the research and development program is focused more sharply and because the results of application to an operating environment are more quickly obtained. Research in advance of operating experience is expensive, because it is far more difficult to prejudge the important areas of unknowns; hence, one errs on the conservative side, tending to research all problems, lest an important one be overlooked. Further, the acid test comes only when the plant is operated so that all environmental factors are simultaneously in effect, as in an actual plant. Operating experience quickly brings the many variables into their proper relative values.

The time element is much reduced in the small plant, and for two reasons. First, since the total dollars involved are much lower, one can afford to take considered risks, eliminating secondary areas of development on the basis of judgment. Second, the far faster fabrication and erection time with smaller equipment makes further acceleration possible. In support of this, may I point out that ALCO

has been active in reactor design for less than 5 years, and we are already well underway on our third generation plant.

Paralleling the above advantages in an intangible but, I believe, nonetheless real advantage of the small plant. Being small, and less expensive, we can afford to parallel development programs and still save money. It has been reported that the PWR cost greater than $80 million. By contrast, the APPR to date has cost about $5 million. We could, for example, have had 10 parallel, but independent programs underway on APPR–1 size plants, for about one-half the cost of the single large plant. Today, we would have 10 experienced groups and, even more important, we would be accumulating 10 system-years of experience each year, instead of only one.

I don't seriously advocate such a lush program, but it certainly gives ground for thought as to the advantages of small reactors.

Chairman ANDERSON. You did hear the testimony, though, that there are certain things you can learn from a large plant that you cannot learn from a small plant?

Mr. KASSCHAU. Yes, sir.

Chairman ANDERSON. Do you believe that?

Mr. KASSCHAU. There are some things that can be learned on the large plant, but I said earlier what I believe, that we can learn substantially all the vitally important things in a small plant.

Although I pointed out earlier that ALCO plans to remain in the small plant field, I find that one cannot completely exclude thoughts with regard to the large plant applications.

With apologies, then, for interfering in other people's business, I would like to recommend that the large reactor plant programs concentrate on efforts leading toward single-cycle plants. That is to say, I believe that the reactor should directly generate the heated thermodynamic medium which is employed in the heat engine.

Even with systems capable of developing high enough operating temperatures to employ high performance secondary systems, as measured by today's standards, the following simple analysis can show the serious hurdle to be overcome in the drive for economic application. In any two-fluid system, the steam generator replaces the boiler tubes, super-heater tubes, et cetera, of the boiler portion of a conventional plant. From there on through the turbine-generator, switch gear, transformers, et cetera, the system is identical with a conventional plant and its cost will be identical at best.

The reactor, its controls, shielding, fuel-handling and waste-disposal systems becomes, then, simply a replacement for the burners and combustion chamber of a conventional boiler. In other words, we substitute complex and expensive equipment for what can best be described as empty space.

If a plant costs $150 per kilowatt, the capital costs contribute about 50 percent of the total power costs in conventional stations. The only place that this high cost can be made up is in the fuel charge. In modern, efficient plants, the fossil fuel cost, even in high fuel-cost areas, contributes slightly less than capital expenses toward the cost of power. This means that any percentage increase in capital costs must be offset by at least the same percentage decrease in fuel costs to break even.

To drive this point home, I should point out that many of the estimates today show capital investments on nuclear plants 35 to 70 percent above the cost for conventional plants. The above simple ratio indicates that fuel cost must be substantially reduced if nuclear power is to compete economically with conventional power.

Obviously, this indicates the importance of reducing capital costs, as has been stated many times before. Although the point has not been driven home, capital cost reduction is not achieved simply by growing larger in size. This is because the same saving available to the very large nuclear power unit is also applicable to the very large fossil-fuel plant.

It is necessary to concentrate on the nuclear portion in order to bring its capital cost down the maximum possible extent.

If we turn attention to reactors producing directly the thermodynamic working fluid, the reactor and its auxiliaries are no longer in competition chiefly with empty space. Instead, they compete with the complete boiler and all its auxiliaries which in modern plants account for 30 to 35 percent of total cost. With this as an area of competition, the financial disadvantage of nuclear capital cost can be reduced to a point that the potential fuel savings may be capable of offsetting the capital disadvantage in a reasonably short time.

I shall resist the opportunity of trying to name a pet system because, in fact, I have no pet. It appears at this point that there is no simple means of achieving the above objective, but just because the objective is difficult is no reason to avoid the issue and ignore its ultimate desirability.

I thank you for this opportunity to be heard.

Chairman ANDERSON. On page 8 you suggest that if these capital investments on nuclear plants are 30 to 70 percent above the cost of conventional plants, that ratio indicates that the fuel cost must be substantially reduced if nuclear power is to compete economically with conventional power.

Mr. KASSCHAU. Yes, sir.

Chairman ANDERSON. If there were some sort of system of grants that might equalize the capital cost between a nuclear-powered and a conventional-powered plant, do you believe that the fuel cost would automatically take care of the difference between them?

Mr. KASSCHAU. I am not sure I quite understand your question, so to make sure that I do, let me state it in my own words.

Chairman ANDERSON. Suppose that the proposal that Mr. McCone made of the Government contributing half the cost of a total plant to the bus bar or the proposal that I, and others have made earlier that approximately 75 to 90 percent of the difference between a conventional plant and a nuclear plant be contributed by the Government in the form of a subsidy, that not to include the generating equipment, would that tend to bring these down to where the fuel cost would not have to be substantially reduced if nuclear power were to compete with conventional power, or would that in itself make it possible to bring it down?

Mr. KASSCHAU. It will very definitely bring it down. To the extent that capital cost exceeds that of a fossil-fuel plant, the fuel cost of a nuclear plant must be less that the corresponding fuel cost of a fossil-fuel plant.

Chairman ANDERSON. Yes; but if you had equalized that by the grant, then what happens?

Mr. KASSCHAU. I am sorry. I thought you said 75 to 90 percent equalization.

Chairman ANDERSON. You should have a little in there for an incentive.

Mr. KASSCHAU. I quite agree. If there is a complete equalization, then the fuel cost of the nuclear plant will have to equal the cost of a fossil-fuel plant in order for the two to be directly competitive.

Chairman ANDERSON. Are there any other questions? If not, thank you very much.

Mr. KASSCHAU. Thank you.

(A subsequent letter from Mr. Kasschau clarifying his testimony follows:)

ALCO PRODUCTS, INC.,
Schenectady, N.Y., March 3, 1959.

Hon. CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy, The U.S. Senate, Washington, D.C.

DEAR SIR: In reviewing the transcript of the testimony of last Tuesday's hearing I see that I was guilty of misunderstanding a straight-forward question with regard to the cost of fuel in nuclear powerplants. With apologies for having misunderstood the question at the time, I should like to make clear my belief on this important point.

A subsidy of 75 to 90 percent (or even 100 percent) of the capital cost excess of the nuclear powerplant over a fossil-fueled plant will not make nuclear power competitive with fossil-fuel power. I expect this condition to exist for some time into the future because there is much yet to be learned about performance of fuels under service conditions. In making this statement I have to draw upon extensive studies we have made of fuel costs for the small-sized reactors which will use fuel elements of characteristics closely resembling those of the large plant.

I feel that my testimony coming as it did on the heels of the PWR tetsimony makes it easy to infer that I am an opponent of the Shippingport reactor. This is not the case, but I base my lack of opposition on the international prestige consideration rather than on the technical considerations to which my testimony was directed. I support the construction of a small number of large powerplants from the prestige point of view, but I strongly favor the small reactor as the development tool which will yield maximum progress for the dollar expended.

I hope the above comments will shed additional light on the information I tried to convey during the hearing. If there is any further information you would like, please do not hesitate to call upon me and I shall do my best to comply.

May I again thank you for the opportunity of appearing before the Committee.

Very truly yours,

K. KASSCHAU,
Manager, Nuclear Power Engineering.

Chairman ANDERSON. Our next witness is Mr. Ellis.

STATEMENTS OF CLYDE T. ELLIS, GENERAL MANAGER; CHARLES ROBINSON, ELECTRICAL ENGINEER; AND PAUL NELSON, STAFF ECONOMIST, NATIONAL RURAL ELECTRIC COOPERATIVE ASSOCIATION

Mr. ELLIS. Mr. Chairman, I feel pretty inadequate among these electric and atomic giants so with your permission I would like to have our staff engineer, Charles Robinson, and our staff economist, Dr. Paul Nelson, here at the table.

Chairman ANDERSON. Let the record show that the giants are down here in the other areas and not on the committee platform.

Again I will say, as I said to the others, that any skimming you can do will be appreciated by the committee. We try to keep everybody to about 15 minutes.

Mr. ELLIS. Yes, Mr. Chairman. I think I shall please you in that respect.

Chairman ANDERSON. Thank you.

Mr. ELLIS. My name is Clyde T. Ellis. I am general manager of the National Rural Electric Cooperative Association. The National Rural Electric Cooperative Association, of which 94 percent of rural electric systems are members, is the nonprofit trade and service organization representing 952 rural electric cooperatives and other nonprofit electric utility organizations in 46 States. In total these organizations serve about 4 million farms, homes and other rural establishments.

I appear before you as I have in the past at these statutory 202 hearings, to express first the continued interest of the rural electric systems in a nuclear reactor program; secondly to comment on the statement of AEC Chairman McCone presented to this committee on February 17 and 18; and last, to again support the positive participation of the Federal Government, for the benefit of the entire Nation, in a program as envisioned in the various Gore-Holifield bills in the past and as set forth in the Gore bill (S. 683) in this session of Congress.

I would like to mention that, at the recent annual meeting of the National Rural Electric Cooperative Association, held here in Washington during the week of February 9, with over 7,000 rural electric leaders attending, they unanimously supported: (1) acceleration of the domestic atomic energy program; (2) adequate participation of rural electric cooperatives, public power districts, municipalities and other nonprofit electric agencies in the atomic energy programs; (3) protection of the people's interest in the atomic energy program; and (4) support of the Federal construction of atomic energy generating plants as proposed in the Gore bill of the 86th Congress (copy of resolution attached, appendix A).

(Appendix A referred to follows:)

APPENDIX A

RESOLUTION PASSED UNANIMOUSLY AT 17TH NATIONAL RURAL ELECTRIC COOPERATIVE ASSOCIATION ANNUAL MEETING, FEBRUARY 12, 1959—SUBJECT, ATOMIC ENERGY PROGRAM

Whereas the rural electric systems have urged that the Congress provide for acceleration of the atomic energy program; and

Whereas the rural electric systems have also urged that the Congress provide the opportunity for adequate participation of rural electric cooperatives, and other nonprofit electric systems; and

Whereas the atomic energy program belongs to all of the people and should be protected from monopolistic abuse: Now, therefore, be it

Resolved, That we urge the 86th Congress to provide an atomic energy power program that will be for the benefit of all of the people and, in particular, will provide for Federal construction of atomic power generating plants as proposed in the Gore bill of the 86th Congress, with preference in the sale of any power therefrom being accorded to rural electric cooperatives, municipalities and other nonprofit consumer-owned agencies; and be it further

Resolved, That rural electric cooperatives, public power districts, municipalities and other nonprofit agencies be afforded an opportunity to participate in the Atomic Energy Commission's reactor demonstration program.

RURAL ELECTRIC COOPERATIVES' CONTINUED INTEREST IN PROGRAM

Mr. ELLIS. Our continued interest in the atomic energy program stems from our desire to maintain the rural electric cooperative program as a going concern—as an integral part of the electric utility industry of the United States—in providing adequate electricity to all persons in our service areas at the lowest possible cost. It is common belief that in the years to come, generation of electric energy will emanate, to a larger and larger degree, from nuclear power technology. We believe it is mandatory for the rural electrics to participate in this program if they are to protect themselves agains extinction—if they are to continue to maintain what little bargaining power they have for wholesale energy and if they are to continue to operate as a competition—by example, yardstick—in the electric utility industry.

As you know, we purchase at wholesale most of the power we distribute. Our wholesale requirements are doubling about every 5 to 7 years and new sources of power at rates we can afford to pay are becoming increasingly difficult to find. While our wholesale costs of power average about 7.5 mills, we are having to pay in many areas from 13 to 20 mills—and often with restrictions on our use of it.

I should say that one of the co-ops, and it is a large one, which is paying approximately 13 mills for power, is not very far from the city of Washington.

We feel that in order for the rural electrics to continue to serve their member-owners efficiently, a way must be found to develop economic nuclear powerplants in the range of 5,000 to 50,000 kilowatts of electrical capacity. Further, we feel that the managers and personnel of the rural electric cooperatives must have the opportunity to become familiar with nuclear power technology so they will be able to move quickly and with ease into this new technical area, since the technology is of no value without the commensurate knowledge of how to most efficiently use it.

Finally, we believe that the experience gained by rural electric cooperative participation in this program can aid materially in expanding the nuclear power art for the benefit of not only the entire Nation but the entire world.

INTERNATIONAL ASPECTS AND IMPLICATIONS

I need not dwell long on the international implications of our atomic energy program. The competitive situation—race if you will—in which we are involved, not only with Russia but with other nations, demands rapid acceleration and fruition of our activities in this program. Our progress in this program, to be sure, is a relative matter to be measured not only against our own accomplishments and achievements of the past, but also against the progress of other nations.

In contrast to the rosy picture painted by the current Chairman of the Atomic Energy Commission, we certainly cannot agree that relatively the United States has made substantial progress in the last 5 years in nuclear power development. I believe several members of the committee most adequately summed up our progress in the last 5 years—or lack of it—with such words as "miserable." In my opinion, the AEC's atomic energy program has "fizzled."

One observer of the progress made by the Soviet Union was Dr. W. H. Zinn. Two short statements from the Zinn report will suffice to describe the great strides, in the eyes of Dr. Zinn, that the Russians have made:

> Perhaps the strongest impression which I have acquired is the fact that technical progress (in the U.S.S.R.) is rapid, and that it is closely coordinated with a program of building intermediate- and large-scale power reactors. The fact that there are now under construction fairly large reactors involving technology which the U.S.S.R. obviously did not have in hand in 1955 indicates that the research and development supporting effort as well as the program of reactor construction, must be large and vigorous * * *

Another observation which Dr. Zinn made on the U.S.S.R. program was:

> * * * that it is comprehensive, as is that of the United States. Practically all of the principal types of reactors under exploration in the United States also are being explored by the U.S.S.R. It seems to be a matter of definite policy to explore all possible avenues for power reactors and to follow promising avenues to at least the stage of an experimental nuclear powerplant—this plant would quite like it have a size of about 50 electrical megawatts. Where there is less doubt about the technical feasibility, it also seems to be a matter of policy to follow up the large-scale experiment with a major power station having a rating of from 250 to 600 electrical megawatts (letter from Dr. W. H. Zinn, president, General Nuclear Engineering Cooperation, to Joint Committee on Atomic Energy, dated October 21, 1958).

John Gunther in his recent volume entitled "Inside Russia Today," also had some very interesting comments to make on the rapid progress in the development of nuclear power in Russia. He stated that:

> Some 55 miles from Moscow is the town of Obnisk, where the Academy of Sciences has another interesting installation. Here, a few years ago, Russian engineers set up the first atomic station in the world for the industrial production of electricity. (The British built an experimental plant to feed actual atomic power into a grid, through which electricity is distributed to consumers.) This station is small—5,000 kilowatts—and serves only a handful of communities in the neighborhood but it may be an important augury. It consumes about 30 grams of uranium a day, an amount the size of a walnut; an ordinary fuel-driven plant would need about a hundred tons of coal per day to produce the same amount of electricity. Meantime the Russians have gone ahead with other atomic power projects. One major station, with an estimated power rating of 420,000 kilowatts, has been completed and is scheduled to go into operation early in 1958; four others are to follow with capacities even greater, the output of which will, Soviet authorities assert, be integrated into the existing electric power system, and will give fuel and light to whole cities. Localities of the four have not been revealed, but different experimental types of reactors will be used in each, according to the official Soviet announcements. * * *

Another vital part of the international picture with which we must be concerned is the role the United States must play in creating and providing a way to bring low cost nuclear power to underdeveloped nations. As Dr. Bhabha of India pointed out in his talk at the 1958 Geneva Conference, and as the National Planning Association has stated, there is a pressing need for the development and use of small- and moderate-sized nuclear powerplants in these areas, not 5 or 10 years hence, but right now.

Therefore, we feel that a positive program of research, development, and construction of reactors in this size class would benefit not only the rural electric cooperatives and municipalities in this Nation—and the privately owned public service electric companies—but the experience and knowledge gained by construction and operation of

reactors in this size class would be of great aid to our foreign allies, as well.

The studies underway at the Rural Power Cooperative Association at Elk River, Minn., on the reactor under construction indicates that the cooperative may be able to double its capacity over the original estimated capacity of 22,000 kilowatts from the given unit and have an eventual power cost of between 7 and 8 mills per kilowatt-hour at an 80 percent load factor. As the members of this committee well know, a 7 to 8 mill cost per kilowatt-hour in many areas of this country is certainly competitive power now. And in foreign nations, even a 12-mill cost per kilowatt-hour of power is better than a competitive rate compared to their existing power costs. Indeed this would also be so to the rural electrics in many parts of the United States now.

I was interested in hearing the reports on the Shippingport plant which indicates much of the same. In other words, the whole trend seems to be more output from the plants than originally planned. We were very conservative and that was very wise. The whole outlook as we go along becomes more and more optimistic. We believe that, certainly.

At this point I would like to comment on the statement that has frequently been made and supported by many to the effect that the United States is not engaged and should not engage in a kilowatt race with any nation in the nuclear power field. According to this logic we should concern ourselves with research and development and wait until the "future" whenever that is, to actually construct and operate nuclear plants. Perhaps the level of abstraction and logic which supports such a statement escapes me, but in my opinion, a research and development program of and by itself is completely meaningless. That is to say, unless we can positively show that our research and development program can and in fact does lead to the production of reactors which provide us with economic, low-cost power no research and development program can be considered worthy of the name. Therefore, in my opinion, we are and must be engaged in a kilowatt race whether we like it or not, and the fact that we have ample fossil fuels in many parts of the country to provide us with relatively low-cost power is not germane to the issue whatsoever. It would be just as logical to argue that we should never have taken the "gas-driven buggies" off the drawing board as it is to argue that we do not need producing reactors, since the already ample horses and buggies eventually got you where you wanted to go.

COMMENTS ON CHAIRMAN M'CONE'S STATEMENT TO THE JOINT COMMITTEE ON ATOMIC ENERGY PURSUANT TO THE STATUTORY 202 HEARINGS

I would now like to direct my comments to the statement Mr. McCone submitted to this committee on the 17th and 18th of this month. First, as to his statement, concerning the AEC's patent policies. Since we hope to testify before this committee when specific hearings concerning the AEC's patent policies are scheduled later this spring, suffice it to say now, as pointed out in our letter of April 24, 1958, to AEC, that the rural electric cooperatives are unalterably opposed to any change in section 153 of the Atomic Energy Act of 1954. Further we firmly believe that this section of the act should be extended for a

significant time in the future, with periodic review to determine whether or not any relaxation or strengthening of the compulsory cross-licensing is in order.

As has been pointed out by two of our Nation's leading economists, Walter Adams and Horace M. Gray:

> It should be apparent, then, that the argument that the ordinary patent privileges should apply to atomic energy in the same way that they apply to other fields is not justified by the facts, at least at this time. To say that everybody has an equal opportunity to patent inventions and discoveries is misleading and disingenuous. It is not equal opportunity to open the door to any and all comers, when some are on the doorstep and others are miles away. It is not enough to define free enterprise like the elephant, who, dancing among the chickens, shouted, "It's every man for himself." Whether compulsory licensing of patents should be the rule for another 5, 10, or 15 years is almost impossible to say at this moment, but the better part of wisdom would be to continue compulsory licensing long enough to assure broad participation in the industry and development along competitive, rather than monopolistic, lines. Let the race go to the swift, but only after all contenders have had a chance to move up to the starting line (Adams, Walter and Gray, Horace M., "Monopoly in America," The Macmillan Co., 1955, p. 149).

Next, I would like to make reference to paragraph 66 of Mr. McCone's prepared statement. As we informed this committee in executive session, we believe that the suggested establishment and achievement of competitive nuclear power in this country within a period of as long as 10 or 12 years establishes too long a time period and one so far in the distance that we may find oureslves 10 or 12 years hence sadly deficient both domestically and internationally in terms of actual operating low cost nuclear power units. It is my belief that the establishment of a time period of not to exceed 5 to at the most 7 years would force the issue to the point where we could be more assured of substantial competitive nuclear power in this Nation, not too far behind what may be expected of other nations.

Secondly, I believe we should work for competitive nuclear power in foreign friendly nations and in some parts of our own, not with a goal in mind of 5 years but within a time period of immediacy. (We all realize, of course, that a given reactor might be feasible in Calcutta or Anchorage and not in Spokane.)

Reading the statements made at the Geneva Conference and other statements concerning the desperate need for energy resources in foreign nations, I feel that we could do nothing better for our existing allies and those we wish to make our allies than to assist them in creating the necessary technology to immediately provide them with a source of relatively low-cost electric energy. (Either we will do it or Russia will do it, and Russia may do it anyway.) Also, I might say, more than parenthetically, there is also nothing better we could do for several hundred of our rural electric systems and other nonprofit utilities.

Concerning points 3 and 4 under paragraph 66, I can certainly support and commend AEC for their statement that they will undertake a continuing long-range program to reduce costs of nuclear power in order to increase its economic benefits and to maintain the U.S. position of leadership in the technology of nuclear power. I would question, however, the method to be used, as suggested by Mr. McCone, in bringing about such a reduction in cost of nuclear power. I would also question, as did Senator Gore and Congressman Holifield during the

cross-examination of Mr. McCone, whether or not we are to date, in fact, the leaders in this program. I think he is wrong. And I believe much of the world thinks so too. Further, in accordance with Congressman Holifield's analysis, even assuming we today are the theoretical leaders in the program, can we maintain this questionable leadership based on the program which the AEC has submitted for consideration by this committee?

If Senator Gore and Congressman Holifield are correct in their analysis, and I have no reason to doubt it, then we must certainly agree that it is difficult for anyone to believe that the AEC is undertaking a role of "positive and vigorous leadership" in the peaceful uses of atomic energy. We've been hearing hollow, boastful, and misleading statements from AEC for too many years now.

From our own viewpoint—that of the rural electric systems—it would seem that there is nothing either positive or vigorous concerning the leadership of the AEC in this area. As the committee knows, three rural electric cooperatives submitted proposals under the second round demonstration reactor program. One of them, the Wolverine Electric Cooperative in Michigan, has since been eliminated.

I did not know until arriving here this afternoon that they had progressed to the point in new negotiations that they may submit another application.

Chairman ANDERSON. Do you think they could under the 50 percent grant proposal?

Mr. ELLIS. No. I didn't hear them testify. I understand that they would have to do this under the old round 2 specifications.

Chairman ANDERSON. There is no old round 2 any more.

Mr. ELLIS. I mean only if it were opened up again.

Chairman ANDERSON. So the proposals of the members of the committee to open up round 2 is probably the only hope that Wolverine would have to get back in.

Mr. ELLIS. That is my understanding.

Representative HOLIFIELD. You mean Chugach?

Chairman ANDERSON. No, we were talking about Wolverine.

Mr. ELLIS. The same would be true of Chugach.

Chairman ANDERSON. We raised the question the other day, Mr. Ellis, if we forget round 2 and did not renew it—I hope we will open it up again—and Chugach or Wolverine or some other similar group came in under the formula that Mr. McCone gave the other day of a 50 percent grant from the start of the plant to the bus bar, all equipment, nuclear plant and generating plant, would Chugach be able to do it or would Wolverine be able to do it, or would most of the REA's be able to do it? Don't they have to have something like the program 2 that we had?

Mr. ELLIS. We think so. We do not believe they can qualify under Mr. McCone's formula.

Representative HOLIFIELD. The reason is that the REA Act would prohibit them from purchasing any kind of a generating system which was doubtful as to the economics, is that not true?

Mr. ELLIS. That is true. To nail this point down you might be interested in a statement which Mr. Kenneth Scott, to whom the REA Administrator reports in the Secretary's Office, answering a question along this line, made the statement to the House Subcommittee on

Appropriations last year, and I quote from page 1876 of the hearings:

> Since atomic energy facilities in connection with power production are considered at the present time to be experimental in nature—

I don't think that is really material to the rest of the statement, but the pertinent part is—

> REA has not authority to finance the nuclear portion of a borrower's generating facilities.

Chairman ANDERSON. I think it is pertinent, if I may say so. It is the fact that they are still experimental that makes it impossible under the law for REA to give them any money. I think that is the whole problem.

Representative HOLIFIELD. Because they can't prove the economics of it as long as it is experimental.

Mr. ELLIS. That is correct. Of course, we get shocked once in a while in this program in attempting to try to help and work with it. We were certainly shocked to learn from the AEC Chairman's statement here in these hearings that the Chugach proposal has been pitched out the window. We did not know that. We think it is not a good way to advise us. Had we been able to know a little earlier of his attitude we could have checked with Chugach. That is not easy, as you know, in Alaska. We might have been able to help you some in regard to its feeling in the matter in response to Mr. McCone's suggestion.

Chairman ANDERSON. I think the statement has been made that a group has been invited to study the situation. The result of the study has not yet been apparent but the decision on that study has been made.

Mr. ELLIS. This is typical, Mr. Chairman, of our experience with AEC. The doors have been slammed in our face from the beginning. We have tried and tried and tried again to work with AEC. They know of our interest in Chugach. Some of the individuals are fine in working with us, but as a matter of policy they apparently do not recognize us, do not consult with us. We have a study team and have worked a lot on these problems. But they never told us anything like this. It came as a complete surprise to us.

The rural power project at Elk River, Minn., is going forward and from all indications will certainly be completed. We had hoped the Chugach electric cooperative (Anchorage, Alaska) proposal would be approved. But we were dismayed to learn from the Chairman of the Atomic Energy Commission in testimony before this committee on Wednesday, the 18th, that he is seriously recommending its cancellation. To me, this means that in his mind the project is dead.

Possibly the Chairman and his staff are correct in their analysis that the "state of the arts" does not at this time warrant proceeding toward the completion of this project. We don't know. However, it would seem fair and reasonable to argue that the Chairman should have made his thoughts and conclusions known to all parties concerned before virtually announcing the cancellation here in this manner. Certainly a full disclosure of the facts is warranted at this time.

The loss of two of the three cooperative projects, plus the difficulty being encountered by all nonprofit electric utilities throughout the United States in their efforts to secure entry into the atomic energy

program, plus the complete elimination of the second round demonstration reactor program—the only program under which nonprofit organizations in the utility industry can engage in nuclear power activities—forces me to conclude that unless the Congress devises some means to reopen "a second round," there will be no participation by these nonprofit organizations in this program. I must further agree with Congressman Holifield that from all that we can discern, "the only initiative AEC is showing is cutting back projects, and in providing greater assistance to certain groups." These certain groups that are getting greater assistance, to be sure, are not the rural electric cooperatives or other nonprofit utilities.

Now I would like to comment on the way in which the AEC says it hopes to bring about industrial participation in the nuclear reactor program—that is through capital subsidy grants which the Government would make and apply toward the—

capital cost of prototype reactors to utilities willing to construct and operate such reactors under conditions which assure the objectives of the Commission are being met.

Chairman ANDERSON. I might say that the chairman hopes that there may be another program eventually proposed for Chugach which is not as advanced as the one they now have and let us hope that comes forward.

Mr. ELLIS. Thank you, sir. I am happy to hear you say that.

I would like to correct Mr. McCone, who said in answer to a question from Senator Hickenlooper that the "stockholders' money" in the utility industry is being used to finance some portion of nuclear power activities. Prof. R. A. Tybout, of Ohio State University, in a study made in 1957 and reported to the Joint Economic Committee, stated that virtually all costs of private utility power reactor projects are paid for by the public. He stated that the costs of these projects have been allowed by the various regulatory commissions to be charged as operating costs and added to their capital and/or operating expense accounts. Professor Tybout concluded that the costs of these projects would be ultimately reflected in the rates charged power consumers—including us, for we purchase about half our wholesale requirements from the commercial electric power companies. We believe Dr. Tybout is correct and that Mr. McCone is in error.

As a case in point, I recall, that under cross-examination by Congressman Holifield several years ago, Walker Cisler, president of the Detroit Edison Co., admitted that all of his company's expenditures in reactor development is allowed by the Michigan Public Utlity Commission as part of the company's operating expense, and therefore will be paid for by the ratepayers of the Detroit Edison Co.

The public then via the tax route or in the payment of their electric bills will be footing the entire cost of nuclear power activities for the private utilities. Not only will they be required to pay for and hand over these nuclear power projects to the private utilities, but presumably the utilities will be allowed to earn a rate of return on the money and funds which the public has given the utilities to construct these projects.

Representative HOLIFIELD. In other words, the real problem is whether that should be spread over the taxpayers of the Nation or be borne by the consumers of the utility district that is putting up the so-called capital plant investment.

Mr. ELLIS. I really think there are a lot more things involved and I am sure you will agree, but that is the issue on that point.

Even so, this is only part of the problem—a large part to be sure, for it is my opinion that the ultimate subsidy the private utilities would receive under this program being advocated by the Chairman of the AEC—would ultimately rival the subsidy now being received by the utilities under the tax amortization and liberalized depreciation (secs. 167 and 168 of the Internal Revenue Code) program.

But Mr. McCone's program would involve an outright grant—a gift—or, to use a dirty word, a direct cash "subsidy" to the private utilities. Presumably, complete title, regardless of the amount of funds given to the utilities by the Government, would rest in the hands of the utilities; complete control over the project would rest in the hands of the utilities; and patents which might be developed out of such projects would be owned by the utilities.

I think the tremendous new public domain that has been created as a result of the atomic energy program is not one which should be literally given away. I think the title to the plants in these early stages should remain in the public domain, I feel strongly.

The flagrant violation of the public's interest and rights in this matter was at first realized only in part by us for we originally conceived of Mr. McCone's subsidy program to be much smaller in magnitude than what he presented to your committee the other day. When asked by Senator Hickenlooper if the capital grants subsidy would apply to only the nuclear power portion of a project, Mr. McCone very readily and affirmatively replied:

> No; it would apply to the entire project—from the nuclear power portion right up to the bus bar—the subsidy should comprise 50 percent of the entire capital costs of the projects.

Further, presumably the various other subsidies in terms of fuel costs, waivers and research and development would still continue.

In addition to our major objections to the McCone plan, there are other serious objections I would like to raise concerning the effect such subsidies would have on the development of atomic power technology in the United States. In a word, we believe it would lead to serious distortions in the program. First, such capital grants would, by definition, encourage the construction of plants with relatively high capital costs and low fuel, operating, and maintenance costs. Naturally, under such a capital subsidy program there would be a desire to spend any amount of funds necessary for capital investment whenever such expenditures promised savings in fuel, operating and maintenance costs, whereas it could quite possibly be the case that under a no-capital subsidy plan there would be no justification for additional capital investment.

Second, there are a whole host of administrative and regulatory problems which would arise under a capital subsidy program. These would include determining the cost in each specific case of the conventional plant in order to arrive at the capital subsidy amount—assuming it were restricted to that; providing provisions in the contract so that if the estimated capacity of the nuclear project were to be greatly exceeded there would not be a huge windfall to the utility; providing the means whereby the plant would be built as economically as possible—and a host of other problems so difficult to handle that the AEC

could advertently or inadvertently lead itself, the Administration and the Congress down the road to other Dixon-Yates scandals.

Chairman ANDERSON. In other words, if you give them half of the plant they charge rates based on the full value of the plant.

Mr. ELLIS. That is right. As you know, there is plenty of regulatory history to the effect that actually happens.

Representative HOLIFIELD. If we do embark on this theory, we are embarking on a new theory in which we transfer over to private industry a capital plant structure directly and the Government loses its equity there, is that not true?

Mr. ELLIS. That is right.

Representative HOLIFIELD. In setting up this formula would that not in effect be setting a formula which would be applied, let us say, to the difference between building a high dam on the Snake River and a low dam on the Snake River?

Mr. ELLIS. If you sought to apply the same principle there and then applied the effect of it to the rates I think these same people who are advocating this sort of thing would yell to high heaven about it.

Representative HOLIFIELD. Am I not bringing up a point there? Let us assume that the low dam cost X dollars and private industry is putting up the amount. Let us assume the high dam costs 2X dollars. If the Government would step in for the benefit of that region and put up 1X dollars, the difference between the low dam and the high dam, and turn the ownership over to the private utility companies that own the dam, would that not be in effect the same sort of a formula?

Mr. ELLIS. Yes. I think you would have much of the same situation. You would also have in that as in this case the same thing.

Representative HOLIFIELD. We could claim in both instances that the public would be gaining the benefit of the investment.

Mr. ELLIS. You could not prove it. The history again would be that you just don't follow through to the public on these innovations that provide the lower cost energy in the case of the electric utilities. So in my opinion just giving them this won't necessarily get the benefits on to the people.

Representative HOLIFIELD. But if the Government's money was confined to research and development and if the Government's contribution had safeguards put around it so that the results of that research and development did get to all participants in industry, whether they be public, private, other manufacturers or utility companies, then you would in a sense at least be in the moral position of justifying the research and development because the difference would be carried on to all the people and there would not be a loss of general public equity there.

Mr. ELLIS. That is right. You would spread the benefits across the whole economy. You would spread the availability of the benefits to all segments of the electric power industry, including, by the way, substantial segments of manufacturing which do their own electrical power production. So you would tend to get the benefits spread through the entire site through that process as against not doing it where you make the grants specifically as proposed in the McCone formula.

Representative HOLIFIELD. I have not yet accepted Mr. McCone's proposal in this field. Of course, it deserves a lot more investigation or interrogation to actually find out what it means. It has only been given to use in a general form. I have a number of questions I wish to ask along the line of how you would implement this type of arrangement.

Chairman ANDERSON. May we move on? The American Public Power Group supplied a very interesting comment on the grant. I read it and I though it was very illuminating. If you have additional comment we would like to have it.

Mr. ELLIS. Yes, sir. It is my opinion that acceptance of the McCone capital subsidy plan would completely eliminate the role of the Government as protector of the multibillion atomic energy public domain. We believe it is neither economically, morally nor ethically justified to hand over to commercial power companies the research and development which has emanated from the expenditures of some $20 billion of public funds for military and civilian nuclear research, plus providing under the McCone formula a subsidy which would subsidize a major portion of the cost of new generation involving nuclear components. We believe the Congress has a responsibility to continue—and not abdicate—its role as protector of the public interest in this vital matter.

Even if some of the rural electric cooperatives and other nonprofit utilities might be in a position to take advantage of the McCone capital grant subsidy program, and I don't believe they possibly could, I in good faith could not recommend this procedure for development of the atomic energy program for it certainly is not in keeping with democratic principles nor does it in any way protect the public interest.

I appeal to this committee and Congress to consider carefully this McCone plan of providing capital subsidies to the utility industry for construction of nuclear reactors. I humbly submit that this type of attempted solution to the problem is not in the public interest.

As to whether the REA's could participate under the McCone proposal, our people, even if they could, would be inclined to go the other route because the benefits would be spread to all people. If it goes the McCone route as we now understand it, this would not be true.

Chairman ANDERSON. Will you supply us additional information?
Mr. ELLIS. Yes, sir.

SUPPORT OF GORE BILL (S. 683)

I believe, as the National Rural Electric Cooperative Association membership has indicated, that the readily apparent multitudinous problems AEC has experienced in trying—if it has tried—to get an atomic energy program going can in large part be solved by passage and sympathetic administration of the Gore Bill (S. 683).

We feel that passage of the Gore bill—which is not a public power bill as some argue—would, with reasonable AEC administration, give the needed direction and impetus to the atomic energy program that to date has been lacking. We believe so for the following reasons:

1. It would provide the positive means needed for an "accelerated atomic power program" by authorizing and directing the AEC to construct demonstration atomic powerplants "at a maximum rate consistent with the status of the development of the art," with the objective of providing 1 million kilowatts of generation capacity by the end of 1965.

2. It would require the building of several large-scale reactors in order to advance power reactor technology; and

3. It would direct the AEC to "initiate a program for the development of civilian power reactors which offer promise of being economically feasible for commercial use in atomic power plants of 10,000- to 50,000-kilowatt capacity" and for the AEC to construct such prototype reactors as soon as possible. This provision we feel would assure continued participation, along with the reopening of the second round demonstration reactor program, of nonprofit, consumer-owned electric utility organizations.

We sincerely hope similar or identical legislation will be introduced in the House of Representatives, and that the Joint Committee on Atomic Energy and the Congress will favorably vote out and pass this legislation.

Mr. Chairman, we appreciate your letter of invitation to appear before your great committee and express our views on the U.S. nuclear power program.

Chairman ANDERSON. Are there questions?

If not, thank you, Mr. Ellis. I am sorry that somehow we get you at the tail of long days every time, but I appreciate your being patient.

Mr. ELLIS. Thank you, sir.

Chairman ANDERSON. We will meet at 2 o'clock tomorrow afternoon.

(Whereupon, at 5:35 p.m., Tuesday, February 24, 1959, the committee was recessed, to reconvene at 2 p.m., Wednesday, February 25, 1959.)

DEVELOPMENT, GROWTH, AND STATE OF THE ATOMIC ENERGY INDUSTRY

WEDNESDAY, FEBRUARY 25, 1959

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D. C.

The committee met, pursuant to recess, at 2 p.m., in room P–63, the Capitol, Representative Melvin Price presiding.

Present: Senators Anderson (chairman), Hickenlooper, and Bennett; Representatives Westland, Hosmer, Price (presiding), Bates, Holifield, Durham, Van Zandt, and Aspinall.

Also present: James T. Ramey, executive director; John T. Conway, assistant staff director; David R. Toll, staff counsel; George F. Murphy, Jr., professional staff member; Edward J. Bauser, technical adviser, Joint Committee on Atomic Energy.

Representative PRICE. The committee will be in order.

This is a continuation of hearings on the section 202 of the Atomic Energy Act of 1954 as amended, on the development, growth, and state of the atomic energy industry. The first witness this afternoon will be Mr. George B. Foster of Industrial Nucleonics of Columbus, Ohio.

Mr. Foster, will you please come forward?

Mr. FOSTER. Thank you, Mr. Chairman.

STATEMENT OF GEORGE B. FOSTER, INDUSTRIAL NUCLEONICS, COLUMBUS, OHIO

Representative PRICE. We are glad to have you before the committee, Mr. Foster.

You may proceed with your prepared statement.

Mr. FOSTER. It is an honor and privilege for our company to come before this distinguished committee. In this testimony we will report to you on three areas of interest. First, is a review of technical developments in the field of industrial and commercial applications of radioactive materials. Many new applications are being uncovered almost weekly. I will mention some of these with which I am familiar and which I believe will be of interest to the committee. A second area of consideration is the economic impact of this new technology on American industry. The figure on savings seem startling in total; but they are readily substantiated when individual cases are studied, and it will be seen that radioisotopes are making an important contribution to the continuing rise of the American standard of living. Lastly, I will present to the committee some views on the effects of legislative and administrative acts on the growth of this segment of the atomic energy industry.

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There are certain potential impediments which loom up in the interaction of private enterprise and atomic energy. Some of these can be avoided by administration of present legislation. Others are bound up in public attitudes, particularly in the areas of public safety and the current fashion of frightening people into unreasoning conclusions about the hazards of radiation. I feel that the Congress—and this committee in particular—has an apportunity for leadership in the education of public and Government attitudes which will exercise a profound effect on the ultimate potential of this new technology.

The field of atomic energy has been effectively categorized by P. C. Aebersold of AEC into the areas of—

1. The military interest, which is concerned with the national defense aspects of atomic energy.

2. The generation of heat for conversion to electric power.

3. The effects of radiation on materials. This includes experiments in the preservation of food through irradiation, development of improved strains of plants through accelerated mutations, and the induction of chemical reactions through exposure to strong gamma fields.

4. The effects of material on radiation. To date, the greatest number of commercial and industrial applications of radioisotopes has occurred in the area of effects of material on radiation fields. That is to say, one can determine certain physical characteristics of materials when they are placed in radiation fields. Among the properties which are disclosed are density of liquids, weight of solids, and thickness of sheet materials. This technology is based on measurement of effects which are produced in a radiation field by placing a material in that field and observing the effects of a radiation detector.

My remarks are confined to this fourth area of technology.

In retrospect, it has been only 12 years since radioisotopes were made generally available for private development and commercial or industrial purposes. During the first 4 to 6 years of this period, numerous basic studies were conducted on the physics of reactions produced on radiation fields with various kinds and shapes of materials, particularly in this country and in England. Significant investments aimed at achieving commercially acceptable instruments for measuring sheet materials were started in 1950. These were private capital investments. Our own company, which today is only 9 years old, has invested $7½ million of private funds in research and development of new products and markets based on this technology. The products which have resulted have fulfilled their promises of expected economic return through savings in raw materials and process time.

In this area of technology, commercial and industrial measurements employing radioisotopes for process measurement and control have been developed which are based on one or more techniques.

In transmission absorption of radiation, a source of radiation is located on one side of a sheet material and a radiation detector on the other. Instruments of this type can be calibrated to extreme precision and can be made to hold calibration indefinitely. This type of measuring system is used for determining basis weight of paper, thickness of plastic film and sheeting, strip thickness of cold rolled steel and other metals, thickness of lead battery plates, weight of cracker

dough, area weight of rubber tire plies, floor tile, sandpaper, and many other sheet materials moving continuously at high speeds.

This system is also used to measure and control the level of liquids or solids in tanks and bins. By enclosing a fluid in a fixed cross section, such as a pipe, measurement of the absorption of the radiation in the fluid can be interpreted in terms of its density. Applications have been made to accurately measure and control the density of continuously flowing substances, such as fruit and vegetable juices, coal and cement slurries, chemicals used in synthetic rubber, sludges in municipal sewage treatment plants, and many others.

A radiation reflection technique has been applied for continuous noncontacting and nondestructive measurement of the amount of coating of one material on another, such as the measurement of the plating thickness of various metals. Coatings of tin on steel strip and zinc galvanizing are routinely measured in this manner. For the first time a continuous, noncontacting, and highly accurate measurement has been provided for a process which previously had to be adjusted from information often one-half hour old, which was destructive—it left a hole in the sheet—and which was based on only a very small sampling of production.

Another method of measurement of material properties makes use of the secondary radiations produced by irradiating the material with radioisotope emissions. A particularly interesting form of conversion from one type of radiation to another is the generation of X-rays with radioisotopes. The electron emission from certain radioisotopes is allowed to strike a target. This produces a type of radiation essentially similar to that produced by X-ray tubes, but without the attendant complexity of high voltage generating equipment. These X-rays are produced through the natural decay process of beta-emitting isotopes, the process providing the needed supply of electrons and their required acceleration. This phenomenon is now being utilized for many industrial measurements.

I have for the committee's observation an X-ray generator which gives the effective energy of about 100,000 volts. This is a complete assembly. I might add this particular one is not loaded, gentlemen.

Chairman ANDERSON. How big a machine will that replace, or serve the same purpose?

Mr. FOSTER. It would replace an assembly consisting of a high-voltage transformer about a foot square and a foot high, plus considerable electronic regulating equipment.

The usual overall assembly of such X-ray apparatus would occupy a cabinet 3 to 5 feet high, 2 feet deep and 2 feet wide and have a weight of several hundred pounds.

Chairman ANDERSON. How big is that device you have in your hands?

Mr. FOSTER. This is 2½ by 2½ by ½ inches, sir.

Representative PRICE. What is the name of the device?

Mr. FOSTER. The physicists term it a Bremsstrahlung generator. It is a secondary generation generator which operates by the sudden deceleration of electrons striking a target.

Let us examine for a moment our national need for continued development in this area of atomic energy. The Bureau of Census estimates the 1975 population of the United States at around 225 mil-

lion. Compared to 1900, when the count totaled 76 million Americans, our population will have tripled in 75 years.

One of the most important considerations resulting from this startling population rise is the percentage decrease in the American labor force. The greatest population increase is at the two ends of the age continuum—those under 18 and those over 65—whereas the broad area between those limits increases at a much slower rate.

In a practical analysis of these statistics, it is revealed that we must double our gross national product by 1975 in order to maintain the increasing standard of living we have enjoyed in the past—but we must accomplish this 100 percent increase in productivity with an increase of only 33 percent in production force. This 67 percent discrepancy must be absorbed by a stepped-up rate of production * * * that is, by more efficient utilization of our present and future industrial facilities. Whether this is termed "advanced mechanization," "improved machinery," or simply "increased production," the final result must be the same: greater output of better products with less input. In many of America's essential industries, such as steel, papermaking chemicals, food, and petroleum, one contribution to greater productivity and more efficient machine utilization has already been found in the application of the "industrial atom" as used in measurement and automatic control.

The starting point toward optimum production from a continuous industrial process is the availability of instantaneous, continuous, and highly accurate measurement or analysis of product. Through such measurement, continuous feedback control of the process can be achieved. Maximum efficiency is realized in terms of quantity, quality, uniformity, and costs of the production.

Thousands of installations demonstrate that radioisotopes are ideally suited to continuous, noncontacting, nondestructive measurement and testing. First, radioisotopes provide a stable source of energy which has been applied to provide measurement accuracies thought unattainable a few years ago. Secondly, the penetrative nature of emissions from radioisotopes eliminates physically contacting the material being measured. Thirdly, the long, useful life of radioisotopes assures reliability for many years. Finally, radioisotope measurement gauges provide an electronic signal which is proportional to the varying thicknesses or weight of the material being produced. This measurement information is used to intelligently and automatically control the process and also to furnish management up-to-the-minute data on production quality and costs.

Raw material savings automatically result when a production process can be more closely controlled so as to produce a uniform "on-spec" product. For example, suppose a steel manufacturer wished to produce sheet steel one-eighth inch thick. Assume further that the customer has specified that the steel will not be acceptable if its thickness rises above three-sixteenth or falls below one-sixteenth of an inch. This minimum thickness is in reality the control on the specification. Whenever the continuous sheet, moving at high speeds, rises above one-sixteenth inch, steel is being wasted and the cost of this extra material must be borne either by the manufacturer or the customer, depending upon the purchase contract. In practice, the specification is therefore set at a value somewhat higher than the minimum.

How much higher depends on how closely the process can be controlled. Obviously, if the steel in this example is held closer to one-sixteenth inch thickness, both the manufacturer and the customer will benefit. The manufacturer increases his production of acceptable steel, and the customer receives a more uniform product, thereby reducing wear on his tools, dies, and fabricating equipment as well as assuring a higher quality finished product. Other economic advantages include reduced scrap material on start-ups, less mill downtime due to mechanical failures which can be more rapidly observed, and more knowledgeable operation throughout.

In basic industries (steel, paper, rubber, etc.) installations of nucleonic measurement-control systems may cost from $15,000 to $250,000. To justify such investments, extensive economic studies are generally conducted prior to and after sale. Statistics obtained from these evaluations show that remarkable dollar savings are being realized through these applications of nuclear energy. With approximately 4,000 such systems now in operation throughout a broad spectrum of American industry, savings are estimated in the neighborhood of $300 million annually in raw materials alone.

The wealth of a nation is, to a degree, reflected in its steel production. It is interesting to review some of the economic benefits of isotope applications in this industry. In a typical case, nucleonic measurement and control were applied to a cold tandem reduction mill which had been operating with conventional controls. This mill formerly produced 93 percent of cold rolled strip within plus or minus 5 percent tolerance. After the radioisotope application, records showed this same percentage of production within plus or minus 1.3 percent tolerance—resulting in raw material and process time savings of $600,000 a year with an investment of only $56,000.

In another example in the steel industry nucleonic measurement and control were applied to a Sendzimir mill. The best available conventional contacting gauging methods were being used prior to the introduction of radioisotope equipment. A mill operator, using readings obtained from the contracting gage, had been controlling the strip by manually adjusting the screw-down motors on the mill. Past records indicated that under this arrangement 57 percent of the steel was being held within the plus or minus 1 percent tolerance. After the radioisotope thickness gage and automatic feedback control had been applied, 97 percent of the production was held within these plus or minus 1 percent limits.

At one of the largest steel producing mills in the country, more than 30 radioisotope measurement and control systems are used for such processes as reduction of cold rolled strip, the plating of tin on steel, galvanizing, sheet classifying and reclassifying, and other processes. Some of these operations formerly presented hazards to personel using conventional measurement methods. This is an example of the contribution made by radioisotopes to mill operating safety.

Radioisotopes are used throughout the metals industry to perform a great variety of tasks. One watch manufacturer is using an isotope gaging-control system to roll alloys to 126 millionths of an inch and maintain this thickness within 5 millionths. This ultarthin alloy can be compared to an average human hair, which, being approximately 2½ thousandths inch in diameter, is 20 times thicker than this alloy sheet.

Today all American tire manufacturers use nucleonic systems to measure and control tire fabric area-weight. The coating of fabric with rubber is one of the most critical processes in tire manufacture, since uniform thickness of the coated fabric is essential to road safety. Too much rubber on the fabric causes overheating; too thin a coat of rubber causes fabric friction or abrasion. In either case, tire failures may result. Improved product uniformity yields an additional return. Typical installations realize $65,000 annually in raw material savings alone.

The technique of measuring sheet materials before and after a coating is applied has recently been utilized in an installation in the Bureau of Printing and Engraving. This equipment is for measurement and control of the amount of glue applied to postage stamps.

Numerous other installations in the paper industry have similarly demonstrated the benefits of radioisotopes gaging and control. Former methods of intermittent sampling have been largely replaced by systems which continuously measure basis weight and automatically control the flow of raw pulp in the production of paper products such as bond, newsprint, kraft, glassine, and many others. User-confirmed reports indicate process variations reduced by as much as 57 percent. Downtime or nonproductive time has been reduced by one-third. On widely used Fourdrinier papermaking machines, yearly savings from $65,000 to $200,000 per machine are achieved through these uses of nuclear energy.

The plastics industry shows the same economic trend wherever nucleonic systems are in use. In one instance, an annual raw material saving of $42,000 is being realized by a manufacturer on a process by which paper is impregnated with phenolic resin. In another case, a film manufacturer eliminated 75 percent of off-weight production to reach an annual raw material savings of $21,600.

The typical case histories mentioned here reveal the broad application of radioisotope measurement systems throughout industry by both large manufacturers and small businesses.

Radioisotope gaging techniques are being applied to new applications at an increasing rate. These applications are not only in new industries, but are performing new kinds of measurements.

The food industry has commenced use of these gaging techniques in the control of fruit juice concentrate processing, in which the amount of natural water remaining has critical effects on the flavor and keeping qualities of the fruit juice. The weight of dough in bakery goods is being measured and controlled at a point prior to baking. At this stage of processing, deviations from specification weight can be rapidly detected and corrected. Cracker lines are now using this type of instrumentation. The filling of cans with food products and beverages is monitored by measuring the effect of the can's contents on the strength of a low energy radiation beam passing through the can. These fill control systems are able to control height of food in containersto plus or minus one sixty-fourth of an inch, enabling food processors to produce "more cans per gallon" by eliminating the general practice of overfilling to assure minimum contents requirements.

Breweries are now using nucleonic inspection-rejection systems for inspecting individual cans for proper fill height. At a signal from the inspection device, an improperly filled can is automatically rejected

from the conveyor line. This job was formerly done manually or by means of a complete X-ray generator installation. An enormous expansion of radioisotope uses in the food industry can be expected, because of the advantages they can achieve in improved cost control and better products. The control of weight of food products has particular significance because of the policing of the net weights of individual packages shipped in interstate commerce.

Recent installations of radioisotope devices in the measurement of the level of hot molten substances have been very successful. Among these are the measurement of molten glass in a melting furnace. The feasibility of measuring the thickness of sheet glass in its hot state has also been demonstrated. Glass must be removed in the grinding operation which makes plate glass, so closer control over the thickness of the sheet fed to this operation will produce significant process savings.

In the manufacture of portland cement radioisotope gaging devices have already found important uses in controlling the rate of feed of clinkers into rotary grinders. A radioisotope source looks through the steel walls of the grinder to reveal the level of clinkers inside. Measurement of the density of the water slurry used to transport cement to driers is now being made by radioisotopes. The injection of the maximum amount of cement and the least amount of water is important economically because the water must later be dried out by heat and evaporation.

One of the most spectacular recent applications of radioisotopes, and one which holds promise of virtually revolutionizing certain aspects of municipal operations, is the work which our company has done in sewage disposal plant instrumentation. While the chemistry of all the successive steps of sewage treatment is not an appropriate matter for discussion here, suffice it to say that the size of any sewage disposal plant is governed by the peak demands made on it for disposal of the solids content of incoming raw sewage. Through radioisotope gaging, a continuous measurement of the solids content of sewage has been achieved. This is accomplished by a radiation source shining across a section of pipe through which the incoming sewage passes.

A radiation detector is able to convert changes in the relative amount of radiation passing through the pipe into an indication of the density of the fluid in the pipe. The density of the fluid depends on the solids content of the sewage. With this continuous data, and by use of other measurements which can be made with present technology, sewage plant operators have an opportunity to double the capacity of present plants or to cut in half expenditures for new facilities. The economics of this situation border on the fantastic. Annual expenditures for new sewage disposal plants are estimated at $2½ billion.

There are also possibilities of radioisotope instrumentation of water treatment operations. Of interest, too, in water supply studies, are the snow depth gages employing radioisotopes which have been successfully tested in the Rocky Mountains over a period of several years, and the soil moisture content measurements employing the combination of gamma and neutron radiation absorption observations.

One other aspect of radioisotope measurement and control must not be overlooked. This is the fact that atomic energy has bridged the communications gap between production line and management. In

systematic conjunction with nucleonic control, data processing, and read-out equipment present management with up-to-the-minute production statistics, economic computations, and overall operational facts. From this continuous flow of data, management has the information needed to make important decisions.

Development of the industrial applications of radioisotopes in the United States is distinguished from other components of the Nation's atomic energy program in that this development has been carried on with private capital investment. Companies in this field have received quidance and timely suggestions from many individuals in the AEC.

Our own company well remembers the leadership demonstrated by Allen S. Lough on safe isotope encapsulation techniques; by George Manov on shielding design; by Bill Morgan on radiological measurements and records; and, of course, by Paul Aebersold on exploring new applications and promoting the availability of new isotopes. Rod Mason's work in licensing administration has been particularly appreciated because of the effort and understanding of the problems peculiar to our industry. Mason's assistance saved many months of development time in new gaging equipment design projects.

The Office of Industrial Development, established during Dr. Libby's tenure, has achieved formal and well-deserved status and recognition for work done over the years informally to promote industrial uses of isotopes.

One of the most difficult tasks assigned to the licensing branch of the AEC under the McMahon Act and again under the 1954 act was authorizing new uses of isotopes. Although the AEC has been assigned monopolistic control of the distribution of isotopes, I do not recall a single private industry development program which has been delayed because of administrative slow motion. The technical competence and ability to get results has been outstanding in the various branches of the AEC dealing with these matters.

However, the individuals responsible for the administration of the regulations are subject to extraordinary pressures to apply unrealistic restrictions in the name of safety. Present regulations controlling the possible exposure of personnel to radiation hazards are, in my view, more than adequate. The safety record of the industry speaks for itself. We hope the administration of regulations will be permitted to keep the relative hazards of the atomic energy program in proper perspective.

Our view is that the hazards attendant to bomb development and testing and power generation are entirely different from those which exist in the uses of isotopes in industrial operations. The radiation levels to which some groups advocate lowering possible exposure border on the unrealistic. If adopted, they could well stifle development in this field. One might compare some of these proposals to suggesting that wall electrical outlets have no more power than a flashlight battery because they might otherwise cause injury or death. Our own gage installations expose process operating personnel to less radiation than is absorbed by the wearing of a luminous dial wrist watch.

Radioisotopes constitute a hazard as does any other source of energy. We believe design principles which assure safety are well known, and are backed by over 10 years of favorable experience.

The AEC recently has adopted new licensing policies in recognition of this fact. These will go far in accelerating further development in this field and a lessening of the paperwork load in administrating byproduct material licensing. This program parallels the development of codes of safe practice and design which have been long established in the electrical and chemical industries.

Without a doubt, the greatest deterrents to continued progress in realizing the benefits of the peacetime atom are misunderstanding and apprehension in the public mind regarding the hazards in this field. There is a lack of understanding of the differences between the real and the imagined dangers. Part of this is unavoidable because of the destructive manner in which atomic energy was first introduced to public notice. Possibly the course of development of electricity would have changed had the introduction of this universally accepted servant been through announcement of an electrocution. Our segment of the atomic energy industry needs to assert itself in the area of placing its radiological hazards in proper perspective. Unknown to the public are the many formerly dangerous tasks to which isotopes have been applied. These include measurements of molten and corrosive materials, the measurement of rapidly moving strips of metal, and measurements in rolling operations.

We solicit the assistance of the Joint Committee in developing a public education program as may be deemed appropriate. We suggest the committee consider supporting studies of the public attitude in these matters. Certainly a broadened activity of public education on the facts concerning the radiological hazards of isotopes in relation to their benefits can be one of the most important contributions to the entire atomic energy program.

Chairman ANDERSON. Mr. Foster, may I compliment you on two things: First, you went through your paper and did a good job of editing so you stayed within the time factor.

Secondly, I received a telegram from a former very highly regarded member of this committee, Senator Bricker, in which he said you were going to testify and suggested you might have something well worthwhile to offer.

I think you had much to offer. I think this is the first time you have been represented at these hearings and I hope you will be here again.

Mr. FOSTER. Thank you very much, sir.

Chairman ANDERSON. Are there any questions from the committee?

Senator BENNETT. May I note for the record that Senator Bricker has been so much impressed with the work of this company that he has asked Senator Hickenlooper and myself both to make sure we were here. I am very glad we were, speaking for myself, and I am sure for Senator Hickenlooper.

Representative WESTLAND. I had not heard from Senator Bricker, but I am pleased I am here, too, because this is new to me and it is of extreme interest, Mr. Foster. I, too, would like to compliment you on your presentation. We have had some reports that there has been a problem in selling these materials.

I wonder, without disclosing anything of a confidential nature, if you could get me a little history of your Industrial Nucleonics Corp. for the past 2 or 3 or 4 or 5 years and its growth if there has been any, and just how you proceeded?

Mr. FOSTER. Yes, sir. Our company is 9 years old. It was formed by a group of engineers in which I am very proud to have participated. We had a number of problems at the outset. One problem, however, I might add, was completely absent and that was the availability of isotopes.

The Atomic Energy Commission extended tremendous help to us in the formation stages of our company in assuring us that the isotopes we would need would be available and, also, in promoting and encouraging us to proceed with applications of isotopes, when some of these isotopes were not yet then available.

I might mention Krypton 85 as one of those. We had many problems of communication with people that we were inducing to invest in our enterprise as to what it was we were proposing to do with isotopes.

After overcoming those difficulities with our investors or potential investors, we again had the same problem with our potential customers as to how we could actually, for example, weigh moving strips of material without touching them.

We found it necessary to demonstrate these phenomena in manufacturing operation in the plants of our potential customers. We found it was not adequate to merely perform laboratory or bench demonstrations. We had to build equipment, to take it out into our prospective customers' processes and demonstrate to them what the measurements were that could be achieved and convince them of the benefits they would achieve.

We have also had to devote much energy to selling industry on the safety of these uses of radioisotopes. We do this by conducting programs for the training of our customers' personnel, by publications in professional journals and, most importantly by citing the safety record of our segment of the atomic energy industry.

We have worked very hard at that and today the selling effort is centered more on the economics of the installations rather than on the demonstrating of the physics of the matter. Our company started with a very few individuals in 1950 and is now approaching 400 in number of employees.

Our sales are over $5 million. We have sold equipment in many foreign countries. Considerable equipment has been shipped to Europe and some to South America.

Representative WESTLAND. Thank you. It sounds like quite a nice little success story, and I wish you good luck in the future.

Mr. FOSTER. Thank you very much, sir.

Chairman ANDERSON. Thank you very much, Mr. Foster.

Mr. FOSTER. Thank you, sir.

Chairman ANDERSON. Mr. Fairman is our next witness. Will you proceed please.

Mr. FAIRMAN. Thank you, Mr. Chairman.

STATEMENT OF JAMES F. FAIRMAN, SENIOR VICE PRESIDENT, CONSOLIDATED EDISON CO. OF NEW YORK, INC.

Mr. FAIRMAN. I am James F. Fairman, senior vice president of Consolidated Edison Co. of New York, Inc.

When I appeared before your committee in March last year, the report of the Edison Electric Institute Technical Appraisal Task

Force on Nuclear Power had just been published. Since then, at least three program statements for nuclear power have been issued—one by the Commission in June 1958; one by the Joint Committee staff; and the third by an ad hoc committee appointed by the Commission. In addition, Chairman McCone outlined for the committee last week the Commission's plans for fiscal year 1960.

The striking fact about all these statements—and an indication of their objectivity—is their agreement as to the status of nuclear power technology. They also generally agree on the types of reactors that show promise. They differ to some extent, however, on the relative emphasis to be given to research and development, prototype plant construction and full-scale plant construction. The report of the ad hoc committee in particular stresses the advantages of prototype plant construction.

The term "prototype" is elusive, and not everyone will concur as to its definition. To me, a prototype is a pilot plant, sufficiently similar to a projected larger plant to prove the technology involved and also large enough to permit some reasonable conclusions as to the probable economics of a full-scale plant. If this definition, while inexact, is conceptually sound, a full-scale plant should not be built when there are unsolved technical problems. The area of maximum expenditures, whether by the Government or others, should also be the area of greatest technological mastery. Conversely, the area of maximum technological problems should be the area of planned, graduated expenditure of both effort and money. Ultimately, of course, the economic potentiality of the various types of plants can be determined only through construction and operation of full-scale plants. There is no difference of opinion on this conclusion. The differences arise in judging whether full-scale plants should be constructed without the experience of prototype plant operation.

The time has undoubtedly arrived to fix definite goals and to look toward them. In that regard it is reassuring that the reports I have mentioned reach similar judgments about the fields of concentration of effort. The agreement implicit in these judgments can form the basis for a national program and, incidentally, for further rounds of the power demonstration program.

I hope, however, that our reassurance will not blind us to the fact that the conclusions of the moment are not founded on a true knowledge about the alternatives. We are still comparatively ignorant about the economics of nuclear power and about the types of reactors likely to make economic nuclear power a reality. This state of relative ignorance continues despite the multitude of studies, speeches, meetings, and hearings that have taken place since the passage of the 1954 act. We must therefore be very careful not to cut off the development of new concepts. Some of these new concepts will spring from Commission laboratories. But they should also be permitted—and encouraged—to spring from private initiative. It would be unwise to establish restrictions on any program which would inhibit proposals from outside the Government involving advanced designs and requiring only modest financial assistance from the Government. I believe that cooperative developmental programs should be fostered even while principal attention is devoted to a few reactor types.

There is obviously no simple way by which economic nuclear power can be achieved. But we should remember that the essentials of the problem are not unique. The Defense Department meets the problem constantly in its weapons programs. Extremes must be avoided. One road that leads nowhere is no better than too many roads that lead nowhere. The avenues of approach cannot be unlimited, but they must not be unduly restricted when the goal is not even in sight.

By this time everyone concerned with this new technology is adjusted to the "hardships of nuclear life." The history of our own Indian Point plant illustrates fairly well the kind of problems the entire industry has encountered.

When we undertook our project early in 1955, we chose a pressurized water reactor since that system was the furthest advanced technically. We thought that the Shippingport experience would minimize our technical and safety problems, and also our financial outlay. This last factor was important to us since we were financing the project from our own funds without any help from the Government or others. We decided at the outset to use a combined uranium-thorium fuel cycle, for two reasons. First, it appeared that we could make a valuable contribution to the limited knowledge on thorium technology. Secondly, lower nuclear fuel costs for the entire industry might be brought about if thorium were developed as an alternate fuel to uranium.

The advantages of our initial decisions cannot yet be demonstrated. Certainly, it did not prove feasible to design our reactor as an exact copy of the Shippingport reactor. As to the use of thorium, its potential as a fuel cannot be fully evaluated until the comparative prices for plutonium and U^{233} have been stabilized. Moreover, thorium technology has presented some unexpected and time-consuming problems. At first we planned to use a combination of metallic thorium and metallic uranium fuel elements. In 1956, however, we received research data which indicated that a reactor core with metallic thorium might fail prematurely. Accordingly, we had to abandon our original core design and turn to an oxide core. Unfortunately, a series of critical experiments utilizing the metallic core was already underway when we made our decision on this change. A second series—utilizing an oxide core—has only recently been completed.

Other difficulties arose out of our desire to reduce fuel cost by increasing the life of the reactor core and at the same time achieving a higher power capability.

Perhaps at this point I should say frankly that, like others with similar projects, we have been concerned about the variation between our original cost estimates and those subsequently recognized. In part this variation has occurred because not enough data existed in 1955 to furnish a basis for reliable estimates. In addition, we have been caught in a general tide of rising price levels for equipment. For example, a year ago I reported that the total cost of our facility was expected to be about $90 million. The present estimate stands at about $100 million and the increase over the estimate reported last year is almost wholly attributable to price escalation.

Despite our share of troubles, we do not regret our original decision to construct the Indian Point plant. Our work with thorium unques-

tionably has produced and will continue to produce new information on this subject which will be of help to ourselves and others. The experience we are gaining in planning, constructing, and operating a nuclear plant will be invaluable to us in the future. Moreover, the plant will produce substantial amounts of power at a cost not unreasonably in excess of the costs of some of our older conventional plants.

One result of the problems encountered has been a slowing of our schedule. In the construction permit issued to Consolidated Edison, the Commission specified October 1, 1959, as the earliest completion date for the reactor, and October 1, 1960, as the latest completion date. It now seems probable that these dates will not be met. Accordingly, we are requesting the Commission to amend the permit to move back both dates 1 year. Our best prediction at the moment as to the actual date of operation is April 1, 1961.

The committee may be interested in some detailed information on our progress during the past year. As you will recall, the plant is expected to produce 275,000 gross kilowatts of electricity. As of January 31, 1959, we had committed $74 million to the project and had actually expended $24,610,000. Contracts for all major equipment, both nuclear and nonnuclear have now been awarded. The functional design of all the reactor systems and components has now been finally worked out with the exception of certain fuel-handling, storage and maintenance components. As I have already mentioned, the critical experiment program has also been concluded, permitting the final nuclear design of the fuel elements and control rods to be fixed. The reactor vessel is about one-half completed, the four heat exchangers are in an advanced stage of manufacture, and the manufacture of the pressurizer has started.

All the site preparation work has been completed. Foundations are in place for the reactor, the turbine room and superheaters. The external biological shield—which is of concrete and over 5 feet thick—has been constructed. The containment sphere, which will be inside the biological shield, will be completely erected and pressure tested by May 1 of this year.

In preparation for the eventual operation of the plant, we have already begun to train personnel who will be involved in its operation. Over the past year 30 people have received extensive instruction in the fundamentals of nuclear engineering through a course organized and administered by our consultant, Vitro Engineering Co. We have sent five people from our staff to the first class now underway at Shippingport, and we will send additional people to subsequent classes to be conducted at that plant.

I am sorry to say that we have not made any progress during the past year on making arrangements for fuel reprocessing and the related matter of waste disposal. From the utility company standpoint, what I would like to see eventually is a program under which we could turn over to a "fuel merchant" the whole problem of supplying fuel to our plant and taking the byproducts from it. We would like, of course, to be able to receive proposals on a competitive basis for such an arrangement. This is not likely to happen in the near future.

If the operation of large reactors is not to be seriously impeded, the Government, at some point, may have to consider a demonstration program similar to the power demonstration program for the nascent

reprocessing industry. Such a program would involve the development of a concept for a reprocessing plant to handle one type of spent fuel element and carrying this concept through the experimental stage to the construction of a prototype plant to be owned and operated by a chemical company or other appropriate industrial unit. Experience with a number of relatively small plants, each handling a different type of spent fuel and each operating at a good load factor, might well offer a short-range economic solution and also point the way to further progress. It could also be a method of encouraging industrial participation since smaller initial commitments by industry would be needed.

During the year we had an additional informational exchange meeting with the Commission reactor development staff as contemplated in the exchange of letters which I filed with this committee when I appeared before you last year. In August 1958, we filed with the Commission regulatory staff a report on the design and safety characteristics of our containment sphere and on December 11, 1958, met with the Advisory Committee on Reactor Safeguards to discuss this report. We have requested that certain features of the design be incorporated as technical specifications in our construction permit and hope for decision by the Commission on this request in the near future.

On balance, I think we are satisfied with the progress we have made during the past year. We are evaluating our progress with an attitude of realism typical now of the whole industry. It is an attitude which does not hesitate to admit that obstacles have been met but which includes a continuing confidence in the future of nuclear power and the importance of its ultimate benefits.

Chairman ANDERSON. Mr. Fairman, I think you are to be complimented on bringing out the facts of this operation. We do not always find out how these financial details are working out. We are very much indebted to you for saying frankly that this project started out in the neighborhood of $55 million.

Mr. FAIRMAN. Yes.

Chairman ANDERSON. It went to $90 million and now to $100 million and perhaps the end is not yet. We are very happy that you have talked frankly to us about this problem because it is a problem that we have to meet.

I notice on one page that you spoke about the desirability of going ahead with some of these new concepts. These new concepts will spring from the Commission laboratories and they should be permitted and encouraged to spring from private initiative.

Do you have any ideas what this might be and do you have anything in mind where the committee might help?

Mr. FAIRMAN. I don't have any particular concepts in mind, Mr. Chairman. The reason I made that statement, Mr. Chairman, is that there has been some intimation that perhaps the Commission's program would inhibit suggestions from outside. That is the thing I think would be most unfortunate. It at least would make it harder to sell.

Chairman ANDERSON. Are you worried at all if the Government builds some of these prototypes at sites where they are going to use most of the product and therefore you are going to get into an argument about rates and public and private ownership?

Mr. FAIRMAN. I am not worried; no, sir.

Chairman ANDERSON. Advanced concepts?

Mr. FAIRMAN. I think advanced concepts should go through the prototype stage regardless of who does it.

Chairman ANDERSON. Thank you very much. As far as I am concerned, I think you have been a fine witness.

Are there any questions from members of the committee?

Representative HOLIFIELD. There is one question I have, Mr. Chairman.

I notice you referred, Mr. Fairman, to the size of this plant. Would you break down the 275,000 gross kilowatts of electricity from that produced by nuclear fission and that produced by conventional superheaters?

Mr. FAIRMAN. Yes. It is 163,000 with the reactor and 112,000 with the oil-fired superheater.

Representative HOLIFIELD. Is that a gas-fired superheater?

Mr. FAIRMAN. It is equipped so that we can use gas, oil, or coal.

Representative HOLIFIELD. So from a nuclear standpoint this is now 163,000?

Mr. FAIRMAN. That's right.

Chairman ANDERSON. I do want to say to you that the committee has a great deal of sympathy—members do, at least—with your proposal about the construction of these reprocessing plants by private industry. It is a suggestion that has been made several times to the Atomic Energy Commission. They continue to produce these things or work toward them themsleves. I quite agree that is a field where private industry might come in.

Mr. FAIRMAN. Thank you.

Chairman ANDERSON. Thank you very much.

Mr. FAIRMAN. Thank you, sir.

Chairman ANDERSON. Mr. Biemiller will you come forward please?

STATEMENT OF ANDREW J. BIEMILLER, AFL–CIO, WASHINGTON, D.C.

Mr. BIEMILLER. Thank you, Mr. Chairman.

My name is Andrew J. Biemiller. I am director of the legislative department of the American Federation of Labor and Congress of Industrial Organizations. I am also chairman of the AFL–CIO's staff committee on atomic energy.

I am here to present the views of the AFL–CIO on certain aspects of our atomic program during the past year.

The American labor movement has a vital interest in our country's atomic policies and programs. It is the interest of workers handling hazardous radioactive materials. It is the interest of consumers. It is the interest of citizens and taxpayers who want to see our Nation and the world derive to the greatest possible extent and at the earliest possible time the incalculable benefits from the peaceful uses of the atom.

In addition to the brief comments contained in my testimony on behalf of the AFL–CIO, I should also like to submit for the record three statements adopted by the AFL–CIO executive council earlier this month. They deal with atomic power development, atomic radi-

ation hazards, and workmen's compensation, and certain international aspects of peaceful atomic development.

(The statements referred to follow:)

STATEMENT OF THE AFL–CIO EXECUTIVE COUNCIL ON ATOMIC POWER DEVELOPMENT, SAN JUAN, P.R., FEBRUARY 20, 1959

Progress by the United States in getting atomic powerplants into operation has continued to be disappointingly slow. We should not allow more time to be frittered away.

The American program of atomic plant construction should and can be sharply accelerated and expanded. This is needed, and needed quickly, to meet American responsibilities of international leadership.

It is needed to equip the United States with the economic and technical experience required to lead and aid the free world in putting atomic power to widespread beneficial use. A stepped-up program will also hasten the day when atomic power can meet the needs of our own high-cost-power regions at home.

Emphasis in an accelerated program must be on construction and actual operation. We must move beyond our extensive program of research and technology experimentation into the practical application phase. Construction and operation experience, with a variety of types of atomic plants, are urgently needed now to gain the practical knowledge and the insights into cost problems and efficiencies not achievable by other means.

The American lead in technical knowledge and our resources should have produced more such experience by now, but our practical progress has been inadequate because the American program has relied on the unrealistic theory that private industry itself would push ahead to build atomic plants.

Since 1954, when the Atomic Energy Act was amended to allow private activity in the atomic field, the administration has put the initiative for atomic plant construction wholly up to industry.

Industry has not done the needed job. And it was neither realistic nor fair to assume it would, considering the technical obstacles and accompanying cost burdens and financial uncertainties of atomic plant construction. Moreover, much of private industry has been interested primarily, not in rapid development of atomic power, but simply in keeping the Government out of the power field.

The recent abandonment of a large atomic plant project by two major companies illustrates forcefully both the problems and the stalling and procrastination which have marked too much of American atomic development.

The two companies, the Pennsylvania Power & Light Co., and the Westinghouse Electric Corp., had announced back in mid-1955 that they would build, on a privately financed basis, a 150,000-kilowatt homogenous power reactor to be completed by 1962. This was after the Government had indicated that it might build this type of reactor if industry did not do so.

A year and half later, in early 1957, the companies stated that preparatory work on the project was still moving ahead. At the end of 1957, however, they requested substantial Federal financial aid. The Atomic Energy Commission OK'd the request and Congress authorized the desired Government financial aid. But in December 1958, more than 3 years after inception of the project, the companies have ended up by canceling it, announcing that it is not now "technically feasible."

The Government's policy of "let's wait and see if private industry will do it," should now be buried. The Government must undertake some initiative and action on its own.

While allowing and encouraging private industry to proceed, the Government must itself construct several types of atomic plants. We endorse the accelerated program as called for in the bill recently introduced in the U.S. Senate by Senator Gore, S. 683.

We urge that the Government observe certain principles in shouldering the responsibility for an expanded program of atomic plant construction:

(1) The Government program for getting a number of promising reactor concepts into early practical operation should include both large-scale and small plants. Experience with large ones is needed for the maximum contribution to major power needs. Small plants, in the 10,000- to 50,000-kilowatt range, are most needed by underdeveloped countries and smaller utilities in the United States.

(2) The program should have short-term as well as long-term targets. Concrete objectives of atomic power production at specified economic levels should be set for attainment early in the 1960's to encourage an immediate determined effort. A long-term approach alone, geared to the 1970's, might unduly encourage too relaxed a pace in the early stages.

(3) The Government should extend financial aid to atomic projects carried forward by industry, but must bear in mind that its proper role is not merely to foot the bills or to make atomic power a profitmaking industry. Where the Government does bear a substantial part of the costs, it has the responsibility of getting the taxpayers their money's worth by making certain that the projects are properly administered and that any technical and scientific advances they yield remain in the public domain.

STATEMENT OF THE AFL–CIO EXECUTIVE COUNCIL ON INTERNATIONAL ASPECTS OF PEACEFUL ATOMIC DEVELOPMENT, SAN JUAN, P.R., FEBRUARY 20, 1959

Several international aspects of peaceful atomic development require special attention in the next several months.

(1) The International Atomic Energy Agency desperately needs additional support. In 1953 President Eisenhower proposed the establishment of this world organization and the United States played a leading role in its creation in 1957. But our actions since have not been as generous as our words then.

When the Agency recently made its first request for natural uranium, the United States offered the nuclear fuel to the Agency for about $54 a kilogram, Belgium offered it for $34, while Canada offered the requested amount without charge. The Agency thanked Canada for its donation as "an inoculation of encouragement."

The Agency needs more inoculations of encouragement. It has not had the resources or support equal to its task of promoting the benefits of peaceful use of the atom around the world.

The United States can and should give the Agency the types of support it needs to function as effectively as originally envisioned. It should move quickly and conscientiously to do so.

(2) The United States commendably has acted to provide meaningful aid to Euratom, the cooperative atomic power development program of six Western European nations. The Congress is to be applauded for its approval of this aid program. This is a sound step for bolstering the economic future and independence of Western Europe.

At the same time, there is a danger that our aid may be converted into a hidden subsidy for American nuclear equipped manufacturers. In the negotiations on construction of power reactors for Euratom it should be kept in mind that the objective of our financial aid is, not to enhance the profit column of equipment producers, but to make a maximum contribution to the economic stability of Western Europe.

(3) The International Labor Organization will discuss in June of this year an international instrument on protection of workers against radiation hazards.

Such an instrument to protect all workers potentially subject to occupational radiation exposure should be adopted. To give it the greatest significance, the instrument should be an ILO convention rather than merely a recommendation. The American delegation should press for this objective as a tangible means of contributing to worldwide observance of radiation safeguards for workers.

STATEMENT BY THE AFL–CIO EXECUTIVE COUNCIL ON ATOMIC RADIATION HAZARDS AND WORKMEN'S COMPENSATION, SAN JUAN, P.R., FEBRUARY 19, 1959.

Organized labor has urged rapid and widespread development of peaceful uses of atomic energy—but we insist that it go hand in hand with, and not at the expense of, safety of workers and the general public.

The objective of safe progress has by and large been reasonably achieved thus far in the United States. This is so primarily because control of atomic radiation hazards has been a Federal responsibility. But there has been a concerted and broadening effort to put the job in the hands of the States.

We emphatically oppose any dilution of Federal responsibility for atomic health and safety. The departure from a Federal program would be dangerous because the great bulk of States and localities cannot provide the necessary financial or personnel resources or the continuing interest and attention required for an effective radiation control program. Moreover, abandoning of responsibility to States and localities would inevitably breed a multiplicity of radiation regulations with resulting conflict, duplication, and perilous departure from sound standards.

We cannot afford such relaxation of radiation safety enforcement. The significance of radiation safety goes beyond the number of potential injuries or deaths. Failure to control radiation hazards thoroughly may jeopardize confidence in their controllability with a resulting loss of worker and public confidence and the growth of a fear of radiation which can seriously impede all atomic progress.

"Radiation hazards also have raised special problems in the field of workmen's compensation. Here the States have had full responsibility. They have shied away from needed action as though it were radioactive. They have an almost unmarred record of failure to revise the compensation laws to take account of radiation protection needs.

As was acknowledged in the recent convention report of the International Association of Industrial Accident Boards and Commissions, the organization of State workmen's compensation officials, "there can be little doubt that most workmen's compensation jurisdiction today provide totally inadequate protection for workers against radiation hazards."

The record of continued inaction by the States has made it evident that the only means of gaining necessary compensation protection for the Nation's radiation workers is through Federal legislation.

There is already a Federal safety program, with Federal standards and a Federal licensing system, governing radiation uses. And there is Federal insurance for nuclear reactors providing financial protection to industry and to the members of the public affected in the event of an atomic accident. A companion measure is now needed to provide corresponding Federal action to provide workmen's compensation for the needs of injured workmen.

The Congressional Joint Committee on Atomic Energy has announced hearings early in this session on radiation hazards and workmen's compensation. We urge that it act to have the Congress (1) reaffirm and reinforce the system of Federal responsibility for radiation hazard control and (2) adopt a Federal program of workmen's compensation protection for workers subject to radiation hazards. The appropriate Federal agencies with experience in the health, safety, and compensation fields should be given the full authority and resources to develop and enforce effective radiation control and workmen's compensation programs in all industries involving atomic materials.

Mr. BIEMILLER. I also request inclusion in the record a copy of the AFL–CIO policy statement on atomic energy adopted in December 1957. I urge its rereading, for its recommendations and findings are as pertinent to our situation now as when adopted more than 2 years ago.

(The statement referred to follows:)

RESOLUTION No. 147—ATOMIC ENERGY

Adopted at Second Constitutional Convention of the American Federation of Labor and Congress of Industrial Organizations, December 1957

The peaceful use of atomic energy has caught the imagination of the world. Tht atom stands as a symbol of a brighter future. The AFL–CIO believes that America must strive to transform that symbol into meaningful reality by extending vigorous leadership and aid in accelerating constructive use of atomic energy around the world.

Already many nations have demonstrated their need and eagerness for beneficial atomic uses by undertaking ambitions programs to develop peaceful atomic energy despite limited resources. The prime goal has been development of electric power, although valuable industrial, agricultural, and medical uses are also being sought.

Thus Great Britain has already put into effect the world's first large-scale generation of electric power from atomic fuel. Six Western European nations have established a cooperative atomic power effort, the Euratom program. On a worldwide basis, the International Atomic Energy Agency has been set up by some 80 countries to hasten and spread peaceful atomic benefits.

Russia has not dawdled on the atomic front. It has pushed ahead on major atomic power projects and it has well recognized the world significance of peaceful atomic development by aiding its satellites and offering atomic aid to other countries willing to turn to it.

The United States led the way to development of the atomic bomb and at the end of World War II it led the world in atomic technology. It has since let its leadership fade. It has failed to do all it could or should to provide leadership to the free world in the practical peaceful applications of atomic energy.

Beginning with the passage of the 1954 amendments to the Atomic Energy Act, the U.S. Government has depended primarily on the hope and expectation that private industry in this country would more completely develop the atomic reactors and technology necessary for widespread application of atomic energy to the production of power and other peaceful uses—even though the cost and technical problems are so great and the prospect of immediate financial returns so meager that it is unreasonable and unrealistic to expect private industry to carry forward an adequate program.

The result has been inadequate progress, particularly in the construction of full-scale demonstration power reactors. Without such full-scale reactors, we cannot adequately gain the economic and technical information and experience we must have in order to be able to furnish maximum practical assistance abroad and to achieve more rapid progress toward lower cost power at home.

The Federal Government must initiate a vigorous program of atomic development and world leadership in peaceful applications of the atom. It should make the providing of effective peaceful atomic aid to other nations a national objective of high priority. It must demonstrate that we can apply atomic energy as effectively for the benefit of mankind as we have in developing atomic weapons that can destroy mankind.

Such a program requires that the Federal Government undertake promptly to construct and operate a variety of full-scale atomic powerplants in the United States for demonstration purposes. It is not enough to give financial aid to private enterprise to get it to undertake some of this task. Indeed, there are signs that the financial aid already extended may be so large as to make a mockery of the phrase "private enterprise."

It must also be kept in mind that if the Government is to foot a substantial part of the costs, it must assume responsibility for seeing that the projects involved are properly administered and that all resulting technical and scientific developments remain in the public domain.

The spread of atomic uses is unfortunately accompanied by the threat of radiation hazards to worker and public health and safety. Radiation hazards are too serious to permit questionable safety standards or lax or haphazard application of regulatory measures. Apart from concern for the welfare of individuals involved, the occurrence of major radiation accidents could quickly disrupt atomic development by causing a general loss of confidence in and opposition to peaceful uses of atomic energy.

It is important, therefore, that the Congress review periodically the existing machinery for protection against radiation hazards and take steps to increase the effectiveness of that protection: The Atomic Energy Commission to regulate the industry which it has the obligation to promote. The need for such examination has been shown in the hearing held on demand of several AFL–CIO unions, concerning the safety aspects of the Detroit Edison Monroe reactor project, in which the AEC authorized construction of a dangerous type of reactor in a densely populated area in Michigan.

The Atomic Energy Act imposes on the AEC the responsibility for protecting health and safety in this field. The current effort of the AEC to shift to the States part of its responsibility must be resisted. This effort has been aided by the Council of State Governments, which has recommended that major segments of this responsibility be relinquished to the States. The States do not have adequate staffs or funds to assume these functions.

Even present State functions, such as workmen's compensation and medical care for injured workers, have not kept pace with the risks of this new industry. The States have shown little disposition to modernize compensation legis-

lation to take account of the special nature of radiation effects. Some State compensation laws do not clearly cover radiation injury, others do not allow for delayed effects of radiation, and others are inadequate in still other respects. Amendments on radiation coverage have been enacted in some States, but still have gone only part way toward providing adequate coverage.

The AFL–CIO is convinced that adequate workmen's compensation protection for all workers exposed to radiation hazards can be assured only through enactment of Federal legislation in this field: Therefore, be it

Resolved, That the AFL–CIO dedicates its efforts to gain development of peaceful uses of atomic energy as rapidly, fully, equitably, and safely as possible, so that the atom's promise may more quickly be realized in improved standards of living around the world. To this end, we urge that:

The United States should provide effective leadership and aid in international activities to promote peaceful use of the atom. This should include: (a) full support of efforts of the new International Atomic Energy Agency to aid and share atomic progress for the benefit of the peoples of the world; (b) encouragement and assistance to appropriate regional organizations such as Euratom which make it possible for a number of countries in a particular region to pool resources to develop a common program in the general benefit; and (c) direct U.S. aid to individual countries.

The AFL–CIO endorses the proposal of the International Confederation of Free Trade Unions to establish a liaison office with the International Atomic Energy Agency.

The U.S. Government must undertake promptly to construct and operate full-scale demonstration atomic power reactors.

The Federal Government must also be vigilant to the end that atomic development proceeds in the public interest and Federal licensing standards must be established and maintained for this purpose. While encouraging broader participation by private industry in atomic activities, the public must be given full protection against the development of private monopoly in any aspect of this industry.

The public's interest also requires that full information be provided on peaceful atomic programs. Restrictions on the publication of nonmilitary atomic information should be eliminated.

The program of Federal Government radiation hazard controls must be maintained and strengthened. It must not be weakened through any shifting of responsibility for radiation safety to the States. Problems related to radiation hazards should be reviewed by the most competent medical and public health bodies and the Congress should establish a National Institute of Radiological Health.

At the international level, full support should be given to the development of sound international radiation control measures through the International Atomic Energy Agency working in cooperation with the International Labor Organization, World Health Organization, and other appropriate United Nations agencies. The AFL–CIO also endorses studies of the effects of atomic radiation under the auspices of the General Assembly of the United Nations.

The Federal Government should enact legislation to provide uniform adequate workmen's compensation for injuries resulting from radiation exposure.

The AFL–CIO shall also work for the following objectives:

(a) As peaceful uses of atomic energy expand, appropriate public and private policies should be developed to meet and ease any adverse effects on workers and their industries or communities.

(b) Affiliated unions should cooperate in voluntary manpower, training, and educational programs required to meet the atomic age's needs for competent skilled labor.

(c) A statutory Labor-Management Advisory Committee should be established to advise the Atomic Energy Commission in developing a sound program on matters of particular labor-management concern.

Mr. BIEMILLER. We regret that once again our testimony must repeat in large measure the same points as it did last year and earlier. The basic weaknesses and lacks we outlined then still exist; and we are losing precious time by our indecision. Let me emphasize these points:

1. Atomic power development: We are now paying heavily for the premature and faulty decision made in 1954 that the United States relinquish leadership and direction to private industry in the development of nuclear power.

Industry has not done, nor can it now do the needed job. It lacks the immediate economic incentive, the adequate financial muscle, and the technical resources to carry out effectively such a heavy responsibility.

It is perhaps needless to point out to this committee the harmful consequences of the administration's nuclear power policy. They are reflected in the loss of our country's former position of unchallenged leadership enjoyed at the end of World War II. We have lost many years of time in achieving the goal of abundant, low-cost electric power from atomic generation.

In spite of this situation, the administration continues its blind adherence to a policy and program which is acknowledged even by private industry as bankrupt.

No new civilian reactor powerplants are recommended for fiscal 1960 by the President's budget message, and only a very slight increase in appropriation requests for research. AEC will continue merely to identify desirable projects which should be built and cling to ineffectual partnership arrangements with private enterprise in hope that somehow they will be constructed.

Early this year the AEC-appointed Ad Hoc Committee on Reactor Programs and Policy from the industry and the private electric utilities concluded:

> Either this country continues its leadership at the cost of heavy expenditures or it accepts the probability that there will be no significant nuclear power industry in this country until the technology has been developed elsewhere and can be reintroduced here. This committee knows of little support of the latter alternative.

Nevertheless, there are encouraging signs that the joint committee's long efforts to get on with the great task of instituting a program to attain as rapidly as possible economically competitive electric energy from the atom, and to regard this task as one of national and worldwide importance, may be encountering less stormy weather. We hope that this will be so.

Reactor technology has now reached a stage where realization of the day when atomic power can meet the needs of our high cost power regions at home and among the world's underdeveloped regions appears attainable.

We therefore need the experience in the construction and operation of several reactor types to provide the foundation for a rapidly expanding nuclear power technology. The importance of such a program and its magnitude require strong, positive, and imaginative leadership by the Federal Government for an accelerated, full-scale development program of practical reactor types.

In asserting this leadership, the Federal Government must not only have a clear-cut set of objectives before it, but must as a matter of policy give a high priority to the civilian power reactor development program. We urge that such objective contain specific power goals to be attained in the early 1960's to begin a determined effort and that the longer term approach be built on the foundations of success from our earlier efforts.

We endorse in principle the accelerated program called for by the bill recently introduced in the U.S. Senate by Senator Gore, S. 683. This legislation places the responsibility for carrying out its purposes squarely on the Atomic Energy Commission to develop, build, and operate large-scale demonstration power nuclear-power reactors at AEC installations "at the maximum rate consistent with the development of the art."

We are also hopeful that in this connection studies now nearing completion dealing with the dual purpose plutonium reactor at Hanford, Wash., will conclude that it is feasible to convert to large-scale power features This installation will not only produce plutonium for military uses, but will produce at least a sufficient amount of electric power to serve the needs of the Hanford works.

As a result, about 300,000 kilowatts of power now supplied AEC by the Bonneville Power Administration will be released to its regular wholesale customers for use in helping to alleviate the serious power supply situation in the Pacific Northwest.

Chairman ANDERSON. May I interrupt you to say that I do not want to discourage you too early, but I do not hold out quite as much hope as you do that that study is going to be too encouraging. The study made by the power groups out there, I think both private and public, concludes that the plant might be a convertible type and later converted.

The Stone & Webster study I do not think has yet been released by the Commission but I hope until it is released you will not get your hopes too high because it may be a little adverse.

Mr. BIEMILLER. I regret to hear that. We are very anxious that plant should go ahead.

Plants in the 10,000–50,000-kilowatt range are required as an important element of a forward-looking atomic power development program. Such plants are most needed by smaller electric utilities, both privately and publicly or cooperatively owned, in our own country and by underdeveloped countries as well.

We urge authorization for AEC to proceed to push ahead with advanced reactor concepts and build plants embodying such concepts on a scale of 50,000 kilowatts or less.

It is high time that the Federal Government's responsibility in developing economic power from the atom no longer be restricted to its laying the financial groundwork for making this kind of program merely a source of profit to private industry.

This committee will recall the assurances given year after year by the private electric utility industry that there was no need for the Federal Government to assume any responsibility for undertaking a large-scale reactor development program because they, the utilities, were pushing ahead with a massive one of their own.

But private enterprise now is admitting in muted tones that it is inadequate to the task it assumed with such publicly voiced confidence. None other than the Edison Electric Institute has told this committee that in order to accelerate the nuclear power development program it "might require some assistance in addition to that now provided * * * by the Government." Any Government subsidy program for the electric utility industry as one means toward the end of achieving the national goal of economically priced power in large

quantities from nuclear fuel is fraught with complex policy and administrative problems. It should be pursued only to the extent to which these problems can be answered in such a way as to advance the interests of the United States and is armed with adequate safeguards governing the issuance of such subsidies:

1. Technological advances bringing down power costs should provide for the benefits being passed on to customers in the form of lower electrical rates.

2. New technological and scientific advances in the field should perpetually remain in the public domain to prevent monopolization and stimulate healthy competitive enterprise. The patent provision of the Atomic Energy law, section 153, gives the Commission authority to require cross-licensing of privately owned patents when required in the public interest. Section 153 expires in September of this year. We urge this basic protection be extended indefinitely in this session of the Congress. It will prevent companies withholding patent development and announcements until after this provision of the act dies and ensures freedom of access by all private enterprise to new developments and technical advances.

3. Administration of such a program must contain these basic protections for the public:

(*a*) AEC should have an adequate and skilled staff to administer it.

(*b*) AEC should set the proper direction of the program by selection of reactor types and sizes and reviewing and approving each plant design.

(*c*) There should be open and competitive bidding on construction and equipment of subsidized private nuclear power plants.

(*d*) AEC should determine that project costs are reasonable, establish adequate audit and inspection procedures, and have in the contracts renegotiation clauses to recapture excess subsidies.

(*e*) Every effort should be made to establish the earliest possible termination date of such a program so that industry can finance its own nuclear operations without continuing to ask for more subsidies from the Federal Government.

In short, the desirable role of the Federal Government is not to pick up the check for private enterprise and remove all element of risk simply to allow it to make profits. It is to stimulate and advance the science of atomic power technology in every possible way, but making certain that consumers and taxpayers and our national interest are adequately protected in the process.

Since 1954 there have been legislative efforts, thus far unsuccessful, to enable combinations of private electric utilities to form large generating companies, and escape jurisdiction and regulation by the Federal Government under the Public Utilities Holding Company Act.

The latest such proposal was made last year in testimony before this committee by N. A. Cocke, president of Carolinas-Virginia Nuclear Power Association under the pretext that CVNPA would produce only steam from its proposed reactor and, therefore, should not be subject to regulation under the act's definition of an electric utility.

The public won a hard-earned victory against a titanic utility lobbying campaign when the Holding Company Act was passed and signed by President Franklin Roosevelt. We will oppose any such

efforts to weaken the regulatory authority of SEC as provided by law over utilities, whether operating singly or in combination.

2. Radiation Hazards: We are looking forward to the March hearings before your committee on radiation hazards and workmen's compensation, where we will present our views and recommendations in greater detail.

Meanwhile, let me repeat in the words of the AFL–CIO executive council statement, atomic development should go forward "hand in hand with, and not at the expense of, safety of workers and the general public."

The safe progress that has been achieved so far has resulted from Federal control over atomic radiation hazards. We oppose the efforts being made to place control in the hands of the various States for two major reasons:

(*a*) Most States and localities simply do not nor are they likely to possess in the foreseeable future the "necessary financial or personnel resources or the continuing interest and attention required for effective radiation control programs."

(*b*) There is already a Federal safety program, with Federal standards and a Federal licensing system, governing uses of radioactive materials. Federal agencies with experience in the health and safety field must be given the full authority and necessary resources to develop and enforce effective radiation control programs. All industries using radioactive materials in any form or to any degree whatsoever should be covered.

It is impossible to discuss control of radiation hazards separately from workmen's compensation for ill effects from radiation exposure. The States, which have had full responsibility to enact revised workmen's compensation laws to take account of radiation protection needs have made a record of total failure.

As the organization of State workmen's compensation officials, the International Association of Industrial Accident Boards and Commission reported during its recent convention:

> * * * There can be little doubt that most workmen's compensation jurisdictions today provide totally inadequate protection for workers against radiation hazards.

It is clear that the only means by which workers can gain adequate compensation protection should they deal with radioactive materials, is through Federal legislation.

We most strongly urge the Congress in this session to adopt a Federal workmen's compensation program for workers subjected to radiation hazards.

Industry is already protected by the Federal indemnity program against financial loss from public claims arising out of atomic accidents. It is only simple justice that workers, whose lives might be lost or health and earning power affected, should be assured equivalent protection by the Congress.

Since the States have failed to come to grips with this protection and take the kind of action needed, the Congress should not delay longer.

3. International Aspects of Peaceful Atomic Development.

In 1953, President Eisenhower in his Atoms for Peace speech before the United Nations said that "* * * atomic power is here, now—

today," and promised that the United States would assist other peoples of the world in attaining its benefits.

There has been little administrative leadership to put meaning into the President's words. The Congress, however, is to be applauded for its approval of the treaty designed to give meaningful aid to Euratom, the cooperative atomic power development program of six Western European nations. It constitutes a notable forward step in buttressing the economic future and independence of this region.

We should like once again to warn the Congress to be constantly on guard to prevent our assistance to Euratom from being turned into a hidden subsidy for American nuclear equipment manufacturers.

When the stage of negotiation for actual contracts to build Euratom's nuclear power reactors has been reached, our financial aid should be employed under the basic policy of contributing to the economic stability and betterment of Western Europe and not merely to assure profits to equipment manufacturers.

We urge that Congress give prompt attention to the desperate needs of the International Atomic Energy Agency for support. This entity, proposed in 1953 by President Eisenhower and created in 1957 with the United States playing a leading role, has not had the necessary resources or support commensurate with its vital task of promoting expanded peaceful uses of the atom throughout the world.

It is not enough that we should be the principal agent behind the formation of IAEA. If it is to function, the United States should quickly and conscientiously give it the kinds of support its program requires.

Our citizens and the world are watching to see whether America can rise to its responsibilities in this new, vast, and complex field which can mean so much to humanity. Your decisions made now will help reflect America's image in their eyes.

Chairman ANDERSON. Thank you, Mr. Biemiller. We are always happy to have you here as a witness. With reference to your remarks about the International Atomic Energy Agency, I hope you will read a couple of recent speeches by the director of that group, Mr. Cole, in which he is not as happy with the Agency as some of us hoped he might be.

Are there questions?

Representative HOLIFIELD. I have one question I would like to ask Mr. Biemiller.

On page 3 (p. 285), the paragraph beginning with the words, "Nevertheless, there are encouraging signs that the Joint Committee's long efforts to get on with the great task of instituting a program to attain as rapidly as possible economically competitive electric energy from the atom, and to regard this task as one of national and worldwide importance, may be encountering less stormy weather.

"We hope that this will be so." Upon what do you base that hope?

Mr. BIEMILLER. Our feeling that there is a rapidly growing understanding that there is a necessity for cooperation between all of the elements combined to achieve this end. But I also hasten to add, Congressman Holifield, to be quite candid, that that statement was written before the appearance of the Chairman of the AEC before this committee.

We have been hopeful that some of the tensions that have existed in the past between the Joint Committee and the AEC were going to be straightened out; that this would lead to a closer cooperation and a better opportunity of accomplishing the program which the majority of the Joint Committee has always been pushing.

Representative HOLIFIELD. I would like to say that as far as I know there is no tension between any member of this committee and any member of the Commission. There is a dispute, I think, on the part of some of us in relation to the evaluation of the program which was presented here on the 17th and 18th of this month by Mr. McCone on behalf of the full Commission.

The difference that evolved was based completely on a difference of evaluation of the program and not on personalities. Part of that difference of opinion arose from the fact that several of the projects which were authorized and appropriated for last year—and I call your attention to the Chugach experimental reactor, about $17 million, Puerto Rico reactor, approximately $10 million, Consumers of Nebraska, approximately $50 million, and the Kaiser study which was authorized and appropriated for at the tune of about $51 million, making in all a program of $127 million in round numbers, which was authorized and partially appropriated for last year had the following fate:

Chugach experimental reactor, as I understand it, has been canceled. Puerto Rico reactor, which was to be a reactor in which there will be a development in the art of superheat—and all of these projects incidentally, were brought to this committee by the Commission—has been left out of this year's requirement.

The Consumers of Nebraska, which was also a Commission-sponsored project and which was authorized and appropriated for by this committee, has now, we have been told, received a 2-year postponement.

In answer to my question, Mr. McCone said that they had not contacted the manufacturers or contractors on this matter but they had contacted the Consumers people.

The Kaiser study of $51 million, which was authorized and appropriated for last year, as we understand it, now being modified to the extent of cutting it down from $51 million to $30 million and removing the power machinery part of the reactor which was contemplated by Congress, has been eliminated.

When you make this statement here that we may be encountering less stormy weather, I am prone to make the remark that the storm has hit us and the weather is more stormy. Then we find out that as far as the draft of the authorization legislation which has been referred to us by the Commission is concerned, they have specifically excluded any resort to any second-round formula under which Chugach and Consumers and Piqua and several other projects were made possible.

That has been completely eliminated, so I think your hopes are ill founded and your optimism is unwarranted.

Mr. BIEMILLER. I regret to say, as I said a moment ago, that since the writing of this statement developments have occurred, and that I agree, regretfully, with your conclusions. I am afraid from the tes-

timony of the Chairman the other day and the points that you have made, pointing out the projects that have been dropped, that this Joint Committee has a task on its hands to rejuvenate the program.

I have long had faith, as you know, in the Joint Committee and I am hopeful that you will be able to develop a program which the AEC will carry out. I have a feeling that this Congress would be more receptive to the programs which have been advanced by many of you gentlemen sitting here this afternoon, in the past, and we are quite ready to do what we can to try to strengthen the position which has been espoused by the majority of this Joint Committee in the past.

Representative HOLIFIELD. Of course, we find ourselves in the position of the old adage, that man proposes and God disposes. We have proposed an accelerated program over the years many times to put us in a position to obtain research and developmental information on the basis that we are now receiving it from the Shippingport operation. We had some very fine testimony yesterday that they were getting research and development information on fuel assemblies and fuel consistencies under specific operational conditions which we could get in no other reactor in the world.

Yet, we only have this one reactor from which we can get this type of information. Some of us advocate having larger prototypes of several different types so that we could go ahead and get this additional information.

So far we have not been able to. We have proposed, but the Atomic Energy Commission, no doubt with some pressure from the Bureau of the Budget, have disposed of our plans. Even if we went ahead this year and authorized or reauthorized some of the projects which from widespread consultation with engineers and physicists and experts in these fields we came to the conclusion were valuable, or if we authorized or appropriated for new projects which are at the point of technology where we need to take the stair-step advance in those fields, what assurance can we have that these will not be canceled and postponed or delayed or ignored, even.

The Atomic Energy Commission right at this time is ignoring the mandate of the Congress in the last act. The deadline has passed for industry complying with the so-called Kaiser study. The only project that I know that came in and is in answer to that proposal was the Philadelphia Electric-General Dynamics proposal and this was ruled in noncompliance by the Atomic Energy Commission's general counsel.

Under the mandate given by this Congress they were supposed to go ahead and build this so-called Kaiser reactor. Yet, there is no action that I know of toward fulfilling the mandate of the Congress. So, I am at a loss to know how this committee can do more than it has done in the past to get this program on the road.

If you have any suggestion to make I would like to hear it.

Mr. BIEMILLER. I recognize the problem only too well because as you know I have been following these developments for the past several years on behalf of the labor movement. I presume that this means in one sense that you have become so discouraged in terms of getting action on authorizations that have already been made that you are not even now, in the mood to proceed along the lines of the bills

that you and others have sponsored in recent years for fear you can't get those reactors in operation, too.

This may be one thing that you have to do—to give strict instructions. Then, if you can't get results, you always can go to the people of the United States.

Chairman ANDERSON. Senator Hickenlooper?

Senator HICKENLOOPER. Thank you, Mr. Chairman. I did not intend to get into this discussion at all except for the turn it has taken in the last few minutes.

I have a great many questions that I would like to go into in Mr. Biemiller's statement. There are so many of his statements with which I thoroughly disagree and which I believe are not sustained by the facts, but our time is short, we have several more witnesses here today, and it would accomplish no constructive purpose to canvass the matter at this time, with the shortness of time.

I do want to comment, however, that I think the Atomic Energy Commission has established and has consistently, with high scientific competence, pursued an advancing and developing reactor program on a sound basis.

It is true that they have not gone out and tried to waste a great deal of money on plants that they know would be wasteful and outmoded at the time of completion.

I think that industry and the Atomic Energy Commission have been handicapped by the unfortunate disagreements and constant disputes which have gone on between this committee and the Commission and industry that has been trying to develop this program.

I feel that those handicaps have been real and severe. I do hope that a climate of cooperation can be established where the scientific people can go forward with the technical people in business and industry, whether it is public or private operation, with some confidence and some assurance.

Chairman ANDERSON. Mr. Price?

Representative PRICE. I think the gentleman from California has addressed himself to a specific incident in the latter part of his remarks, where I personally feel the Commission does leave itself open to criticism. That is in the case of the gas-cooled natural uranium reactor on which they had a mandate from the Congress.

The time is running out. I understand they have submitted a list of authorization and that is not in it. So there is some reason for question being raised as to what they intend to do on it.

This could in no way be considered a wasteful project. In this instance the Commission leaves itself open to criticism because it not only does not respond to a mandate from Congress but it does not adhere to the recommendations of its own ad hoc committee which has seen merit in this project and has made recommendations direct to the Commission in time for it to include it in the authorization program for this fiscal 1960.

So I think in the face of a situation like this occasionally they do open the door to criticism. It is not criticism based on a desire to be at loggerheads with the Commission. It is a case of a committee of Congress being interested in an overall program which it thinks is beneficial to the program itself and to the national interest.

I think it is one of the proper functions of a congressional committee.

Chairman ANDERSON. Mr. Hosmer?

Representative HOSMER. Mr. Biemiller, on page 3, at the bottom paragraph, you recommend the construction and operation of several reactor types under an accelerated full-scale development program of practical types.

Over on page 5 you urge the authorization of some 50,000 kilowatts or smaller plants. Are those two different recommendations or are they the same?

Mr. BIEMILLER. Two different recommendations. Both larger scale and the medium-scale plants are our recommendations.

Representative HOSMER. What types do you recommend in the larger scale?

Mr. BIEMILLER. I beg your pardon?

Representative HOSMER. You recommend several reactor types. What specific types do you recommend for this construction?

Mr. BIEMILLER. That is a problem that we assume would be handled by the AEC, as to making the choices between the various types of reactors. What we are arguing for is to take the best scientific knowledge available and to apply it on a large-scale reactor program so that we know what we can do in this area.

Representative HOSMER. We are doing that now in the case of the pressurized water reactor and the boiling water reactor. So it would be in some other types of reactors; is that right?

Mr. BIEMILLER. This would be a problem that we would not pass judgment on ourselves. We would expect the scientific experts to pass that judgment.

Representative HOSMER. Then, would not going ahead depend upon the accumulation of a certain amount of technical knowledge and whether or not that now exists you say you are not sure.

Mr. BIEMILLER. We are of the opinion that it does exist, but it is a decision that we as laymen certainly would not make.

Representative HOSMER. Then you would not urge it if the state of technology was not sufficient?

Mr. BIEMILLER. We point out that we endorse the proposal in the Gore bill to proceed as rapidly as you can in terms of the existing knowledge in the art.

Representative HOSMER. Then, whether they were going too fast or too slow or about the right speed, in turn, takes a determination of what the existing state of the art would support?

Mr. BIEMILLER. But there exists, as you know as well as I, Congressman, the opinion of many scientists that we have not proceeded as rapidly as we could.

Representative HOSMER. Then there are others that say the opposite. I point out that it certainly is a matter of opinion and also that is subject to checking the accumulated information.

Let us ask the same questions about the 50,000-kilowatt-or-less plants. Do you have any specific recommendations as to how many or what types?

Mr. BIEMILLER. As to the exact number of anything of that sort? Not at all. We would assume again that this is a matter that the AEC should be proceeding with more rapidly than they have in the past. The ultimate decisions have to rest with such persons.

Representative HOSMER. Then you assume that the AEC has accumulated information necessary for the design and construction of plants that it is not now utilizing for that purpose?

Mr. BIEMILLER. That is our opinion.

Representative HOSMER. Do you wish to say what types it has accumulated this information about which it is not acting on?

Mr. BIEMILLER. This is not a problem on which we would pass judgment.

Representative HOSMER. I am trying to determine actually the weight of your testimony, Mr. Biemiller. That is what I am after. You have charged it is not going ahead fast enough. I am trying to find out in what field it is not.

Mr. BIEMILLER. That, sir, to us is obvious. You have just heard, for example, from your colleague from California, a recitation again of certain projects that have not been carried out that have been authorized.

Certainly, in our opinion—and I repeat, it is an opinion—the art and technology are present which would permit a more rapid development than we have had. One of the things that disturbs us very much is the constant information that we have of other countries proceeding more rapidly than the United States.

That is something that we do not like. We think that other countries are going to beat us to the punch in this whole area.

Representative HOSMER. Let us go from the general, again, into the specific. I believe Mr. McCone's testimony regarding the reason for the cancellation of the Chugach reactor—were you here at that time and did you hear it?

Mr. BIEMILLER. I was not here, sir.

Representative HOSMER. He stated that the reactor was proposed to be built in Alaska at a fairly remote location and that it was an extremely sophisticated type of instrument and it would be difficult to do the job in such a location remote from the laboratory.

If it was going to be done it should be done someplace else. Do you feel that is a logical approach to the problem?

Mr. BIEMILLER. Not having heard the complete testimony this is not a matter I would feel competent to pass judgment on at this time.

I think the members of this committee are in a far better position. I might remind you while we are on this general area that you have had testimony before this committee, for example, from former Commissioner Murray, that there are several areas in which the AEC might well proceed. I think the matter has been aired here at great length as to other areas in which developments might go ahead.

I certainly feel very strongly, as do obviously at least some members of this Joint Committee, that you actually have a situation existing today where the Executive is thwarting the expressed will of the Congress. I think this raises a fundamental problem in American Government and one that has got to be met.

Representative HOSMER. Getting back to the specific question of Chugach, however, is it my understanding that inasmuch as you have not examined Mr. McCone's reasons he gave for canceling the project, you are not in a position at this time either to criticize or to approve his reasons?

Mr. BIEMILLER. What I said a few moments ago was that I am aware of the content of that testimony. I did not hear it. I did not hear the discussion which preceded.

I certainly think I have a right to express the view that it is most regrettable that when the Congress specifically authorizes projects, that they are not carried out.

Representative HOSMER. Does that mean that even though we authorize a project and as research and development goes on it turns out to be a dog that we should go ahead dogmatically with it anyway?

Mr. BIEMILLER. You are making an assumption there that I am in no position to pass judgment on in terms of this given project.

Representative HOSMER. I am just assuming.

Mr. BIEMILLER. I am pointing out that Mr. McCone did not say that about this project.

Representative HOSMER. He gave another reason, and this is another question.

Mr. BIEMILLER. You are asking me entirely different questions. You are trying to shift from a particular to a general.

Representative HOSMER. I could not get an answer on the other one. I thought maybe I could get one on this.

Mr. BIEMILLER. It is perfectly obvious that if you had started research on any project and advanced that research to a point where it was clearly recognizable that the project was not feasible, I would assume that the AEC would come back and make such a report to the Joint Committee, but that is not what happened on this particular project.

Representative HOSMER. No, they had another reason why they did not go ahead with it. In this recommendation on the 50,000-kilowatt reactor concepts, do you feel that the general dynamics proposal fits into that picture insofar as you know of it?

Mr. BIEMILLER. As far as I know, it would. Again, I would not pretend to pass ultimate judgment on the matter.

Representative HOSMER. Thank you.

Chairman ANDERSON. May I ask you this: The heavy water natural uranium device was asked for twice by the Atomic Energy Commission, a fairly large-scale plant. The Bureau of the Budget turned it down twice. This year the Atomic Energy Commission did not ask for it. Do you think that would be one of the things that they twice asked for that offered some promise?

Mr. BIEMILLER. I would certainly think so. As you know better than I, Mr. Chairman, you have had numerous projects before you here that in the opinion of many competent scientists made sense but yet no one has proceeded with them.

Chairman ANDERSON. The gas-cooled reactor that the Congress appropriated or set aside some $51 million—authorized and appropriated about $21 million—is an advanced Calder Hall type which represents a tremendous amount of engineering in Great Britain and followed by a study by Kaiser ACF Industries in this country, a bid was asked for, industry was asked if they wanted to build it.

They did not want it. The law said you should go ahead and build it. Finally, February 21 came and went and nothing happened. Is that one of the things you think should be built?

Mr. BIEMILLER. I should certainly think so.

Chairman ANDERSON. Consumers is a pretty good plant. It involves some $50 million. Engineering has been done by some very good people. It has been put aside for a few years. That means $50 million will not have to be spent for 2 years and will probably help balance the budget.

They would like to go ahead with it; the postponement was initiated by the Atomic Energy Commission, as we understand the testimony, and no consultation with the firm on the west coast that had the engineering work on. That might be one.

Mr. BIEMILLER. Another very good illustration.

Chairman ANDERSON. Thank you.

Mr. BIEMILLER. Thank you, Mr. Chairman.

Chairman ANDERSON. Mr. Menke.

STATEMENT OF JOHN MENKE, PRESIDENT, ACCOMPANIED BY WALTER HAMILTON, CONTRACT DIRECTOR, NUCLEAR DEVELOPMENT CORP. OF AMERICA

Mr. MENKE. Thank you, sir.

Chairman ANDERSON. I should also recognize Walter Hamilton, since he was for so many years a valuable member of the staff of the Joint Committee.

Mr. MENKE. I was going to ask your permission for him to sit with me and to add to the value of anything I might say, since I am sure he can.

Mr. Chairman and members of the committee, my name is John Menke, and I am president of Nuclear Development Corp. of America (NDA) of White Plains, N.Y. Thank you for inviting me to join you today.

In preparing for coming before you, I have reviewed my testimony in these hearings for the past 8 years.

My testimony on these occasions has been centered consistently on two subjects: I have dealt with the problems of a comparatively small, independent company in the field of atomic energy, and I have stressed the importance of heavy-water, natural uranium reactors. Both of these topics are important now, too.

As to the first, I do not think you will be surprised if I remark that small companies growing in the reactor business still have problems. I would like you to keep this in mind through what follows. In this respect I will, of course, discuss the Chugach situation with you.

But my major remarks will be directed to the second subject, because of the importance—which you have recognized—of natural uranium fuels to this country and abroad, and because a reactor operable on natural uranium should be scheduled now.

First I shall speak of the SDR and Chugach.

I. THE SDR AND CHUGACH

1. The sodium-deuterium reactor (SDR) is one particular kind of advanced heavy-water reactor. It is an important concept with high potential, and I believe an experimental reactor should be built and operated. The decision as to an appropriate reactor experiment should be taken after careful consideration and evaluation of the reports

which are to be presented to the AEC during the next months. A conditional authorization may be needed now to make it possible for the AEC to build an experimental reactor.

2. NDA concurs in the AEC position that the first SDR would be better at an experimental station than at a utility site. This is a technically sound decision. It is a better decision than puttng a first reactor at a utlity site but a reactor at a utility site is better than no decision at all.

First reactors of an advanced type are better as reactor experiments because they can be designed and operated more flexibly and yield more information. Also, such reactors at experimental stations can cost less for two reasons: first, they do not need as much power-oriented equipment and, second, safety-oriented costs are reduced by large exclusion areas. In addition, they can be made smaller, which permits further cost reduction.

3. The vicinity around Anchorage is a good place to build a reactor. Chugach Electric Association has cooperated, always constructively, and should be given consideration for an AEC-sponsored reactor. NDA and Chugach have always been willing to proceed together on the original proposal to build a demonstration prototype SDR at Chugach, but we agree with the AEC that it would be more orderly to build an SDR experiment first. I hope that a small experiment will be authorized and built.

Representative VAN ZANDT. Mr. Chairman, may I ask a question at this point?

Chairman ANDERSON. Mr. Van Zandt.

Representative VAN ZANDT. Isn't it a fact that the Chugach project has not been canceled?

Mr. MENKE. The building of a first reactor at Chugach before an experiment has been stopped.

Representative VAN ZANDT. It has been stopped?

Mr. MENKE. It has been stopped.

Representative VAN ZANDT. But not canceled.

Mr. MENKE. The authorization has not, to my knowledge, been withdrawn.

Representative VAN ZANDT. Would you think it would be good procedure in this research and development field, especially in atomic power, to keep this authorization open for at least another year?

Mr. MENKE. It would be useful to do if an experimental reactor were to be built.

Representative VAN ZANDT. In other words, if given an experimental reactor project, it would be a good practical approach to keep the authorization alive.

Mr. MENKE. Yes, it would be a more orderly procedure.

Representative VAN ZANDT. Thank you.

Chairman ANDERSON. Now that the question has been raised, actually haven't they appointed a committee or study group inside the Atomic Energy Commission to study the Chugach situation?

Mr. MENKE. Yes, they have appointed such a committee, and some members of this committee have done us the courtesy of being present today.

Chairman ANDERSON. Has the committee been appointed as yet?

Mr. MENKE. Yes, the committee has been appointed and the first meeting with that committee was last Monday a week ago.

Chairman ANDERSON. Then it possibly could not have reported yet, could it?

Mr. MENKE. The procedure of presentation to the committee will involve more than a month.

Chairman ANDERSON. But in the meantime the Chugach project has been stopped?

Mr. MENKE. Yes, sir, but research and development on the SDR is continuing.

Representative PRICE. Mr. Chairman, may I ask this question?

Chairman ANDERSON. Mr. Price.

Representative PRICE. Will it take more than a study in this situation before you can go ahead with the Chugach project, or would it be necessary to build an experimental reactor some place?

Mr. MENKE. In my opinion it is proper to build an experimental reactor first.

Representative PRICE. What are the purposes of your study, then, if this is the fact?

Mr. MENKE. The purposes of the study were to demonstrate the feasibility of the project and its economic promise. The feasibility has been increased by these studies. The project has become more sensible as time has gone on and the economic promise has, in my opinion, been demonstrated.

Representative PRICE. I think this incident points up the reason that reference has been made to a dog of a project. I don't think it was meant to apply to the Chugach reactor project.

Mr. MENKE. I didn't consider it so.

Representative PRICE. This is one of the reasons that we are dogging the trail of the Commission so much. Here is a case where they have a given reason, and no one has criticized them for delaying the Chugach project, because they have a technical reason to do it. They know what they have to do. What is required here is an experimental reactor.

Mr. MENKE. Yes, sir.

Representative PRICE. If they know that they are canceling this project for that reason, then it would seem to be wise for them to include an experimental reactor in their recommendation for authorization for this year.

Mr. MENKE. I have recommended such a procedure.

Representative PRICE. This is one of the things that has caused the members of the committee to dog the trail of the Commission so often.

Representative VAN ZANDT. You were making a statement a moment ago. Would you repeat it?

Mr. MENKE. I was saying that I didn't understand the word "dog" in Mr. Hosmer's comments to apply to the SDR Chugach reactor.

Representative HOLIFIELD. Mr. Menke, addressing my remark to the first part of your statement—as I understand, you have been studying the design of this reactor at Chugach for how long?

Mr. MENKE. The design was started in January 1957.

Representative HOLIFIELD. That is more than 2 years.

Mr. MENKE. Yes, sir.

Representative HOLIFIELD. What stage had you reached in your design study. Were you ready to go ahead and start building, or were you ready for more laboratory experiments? Just what stage had you reached?

Mr. MENKE. We had completed experiments which demonstrated our capability of controlling sodium and water in the same reactor. We had completed studies on the economic potential of the reactor. We had started a pre-title 1 design of the reactor at Chugach. That is the extent of the work that has been done to date.

Representative HOLIFIELD. Had you recommended to the Commission that the project be canceled or stopped?

Mr. MENKE. No, we had not.

Representative HOLIFIELD. Had you been consulted as to that before they made their decision?

Mr. MENKE. Yes, sir. They consulted us on Saturday, February 14.

Representative HOLIFIELD. The Saturday before they called you in on Monday and informed you that it was going to be stopped?

Mr. MENKE. No, they informed us on Saturday.

Representative HOLIFIELD. They informed you on Saturday and asked you to come in Monday for a conference?

Mr. MENKE. The conference was on Saturday. Everything happened on Saturday.

Representative HOLIFIELD. They called you in on Saturday and at that time you were informed that it was going to be—whether we use the word canceled or stopped, I won't quibble over the word. In either case, as far as proceeding with that project is concerned, the AEC has now said they will not proceed.

Mr. MENKE. The AEC has said that they would not proceed now with a reactor at Chugach. They have said that they will evaluate the work which has been done to date and will consider an experimental reactor at an experimental station.

Representative HOLIFIELD. The group that they have appointed to study it, are to study for what purpose? To evaluate the work that has been done with the possibility of building this type of reactor may be at some other location, or a smaller type of it as an experiment?

Mr. MENKE. That is my understanding.

Chairman ANDERSON. Could we establish the date, first? That would be February 14, Saturday, prior to Mr. McCone's testimony on February 17.

Mr. MENKE. Yes, sir; that is correct.

Representative HOLIFIELD. Has there been any suggestion that a different type of reactor might be substituted at Anchorage for the aforeplanned type?

Mr. MENKE. Such a discussion has been had with the Chugach representatives in my presence; yes, sir.

Representative HOLIFIELD. So there is some possibility, let us say, of going ahead with a reactor at the Chugach location?

Mr. MENKE. Yes.

Representative HOLIFIELD. Of a different type, possibly.

Mr. MENKE. Either a different type now or this one later.

Representative HOLIFIELD. I would say that this committee has shown complete understanding of the cancellation of a project for a

technological reason. I call to mind the Pennsylvania Power & Light project which this committee authorized and for which $7 million was appropriated in the research and development field. When they came before us, the manufacturers and the Atomic Energy Commission, with the decision to cancel because it was thought to be technologically unwise to proceed, and there was a meeting of minds on that point, this committee completely understood that situation. I think in the future, whether it is the Chugach or any other project that is authorized, if it is stopped for technological reasons, I don't think the committee would be in opposition to such a thing.

Mr. MENKE. This is a technical policy reason. It was stopped for a technical policy reason; namely, that it was a type of reactor for which an experiment first is a more orderly and better procedure. I would go along with that. I agree with that.

Representative HOLIFIELD. We are not quarreling with this point. It is one of the cancellations of a series of either omissions or cancellations or modifications which affects the program of accomplishing operating reactors very sharply and delays the consummation of finished reactors to obtain the information which we want from operating a reactor.

Mr. MENKE. That is right.

Representative HOLIFIELD. That is why we are very concerned about these various kinds of reactors that have been canceled or omitted in the program. There may be reasons for all of them, but they will have to be explored during the authorization legislation hearings.

Mr. MENKE. Yes, sir.

Representative VAN ZANDT. Mr. Chairman.

Chairman ANDERSON. Mr. Van Zandt.

Representative VAN ZANDT. I have just one question for the purposes of clarification. Did I understand you to say you had recommended to the AEC that this project be authorized on an experimental basis?

Mr. MENKE. Yes; that is the sense of my remark.

I would like now to turn to the very important subject of our present heavy-water reactor program as distinguished from the particular Chugach SDR program.

The first question you should ask is: Why are heavy-water reactors important?

These are the economic and national policy reasons:

1. They are the only practical reactors which can burn natural uranium, a universally available and low-cost fuel. They can burn it efficiently and can conserve resources.

2. Natural uranium fuel will have a predictable, stable price throughout the life of these plants.

3. By not needing enriched fuel, heavy-water reactors are not dependent on diffusion plants.

I would like to pause here and emphasize that you are not building in a basic conflict between power production and military requirement for enriched fuel in a natural uranium-fueled plant. I point this out to your attention because in my opinion it is one of the most important policy questions in nuclear power in the next 20 years.

In fact, these are the truly convertible reactors. They can be immediately turned to the production of additional plutonium in

large quantities in any emergency. It is not feasible to do this in any other power reactors.

Chairman ANDERSON. Would this have some bearing also on our whole total national defense program?

Mr. MENKE. Yes, sir.

Chairman ANDERSON. Could we not proceed much more rapidly with our weapons program if we knew that we did not have to divide the supply of enriched uranium with the civilian requirements unless it were convenient? For instance, if we had a situation that became very stringent and we needed all of the products of our diffusion plant, they could all go into weapons. But if we build up a manufacturing economy to produce the war goods that went along with it, and if those reactors had to depend upon natural uranium, they would cut down the product of the diffusion plant. They would dip in and take away from the weapons program.

Mr. MENKE. Yes, sir. It is not only weapons, but also military propulsion vehicles which will grow in their importance. The submarine now, and many others, and they will also have requirements for enriched production.

Chairman ANDERSON. Mr. Cole had some idea as to whether a submarine was a weapon or not, and some of us might be regarding it as a weapon. I was taking that into consideration. In other words, the natural uranium plant in time of emergency does not take away from the Military Establishment the production of enriched uranium, plutonium, or things of that nature, but adds to it, perhaps.

Mr. MENKE. Yes, sir. It eliminates a roadblock in military production.

Representative HOLIFIELD. It gives them an additional supply of plutonium which is particularly useful in small weapons.

Mr. MENKE. Yes, sir.

Representative HOSMER. The argument is also predicated on a long war.

Mr. MENKE. It is predicated on any kind of war.

Representative HOSMER. We hear this business of a 15-minute war. It would not apply there, would it?

Mr. MENKE. I am afraid you might have to ask me to amplify in a different session.

Representative HOSMER. Would you repeat that?

Mr. MENKE. If you were considering a saturation effect, the supply of plutonium is important even in a 15-minute war. I don't believe in 15-minute wars, but it is important even in that time during the prewar buildup.

Representative HOSMER. It does somewhat depend on what kind of a conflict might occur, does it not?

Chairman ANDERSON. I would have to agree with Mr. Hosmer, I think. It does to a great degree. We could argue that a long time. Many people think the war can't last more than 1 day. Some are very optimistic. They think it might run 3 days.

Mr. MENKE. This emergency production capability can be widely and safely dispersed. This additional plutonium production potential can be available largely through private investment except for the initial demonstration reactors.

The Joint Committee has recognized the importance of heavy water reactors by initiating a design study to get a demonstration prototype project moving. The first reports have been transmitted; the final reports will be in the hands of the Commission in a few days. The momentum which the Committee and the Commission sought to acquire through the authorization last year has been built up. If we are to capitalize on this momentum, now is the time to go forward directly to the demonstration prototype.

Chairman ANDERSON. There is one question that I wanted to ask that is of interest to producers of uranium in my part of the world. This does provide a ready market for uranium. You don't have to send it all through these other refining processes as is true with the enriched uranium devices?

Mr. MENKE. Yes. In this case the customer can be a commercial enterprise and need not go through a Government plant.

The second question you should ask is: How are we progressing toward accomplishment of this important objective?

Some work on heavy-water reactors is in progress. Two test reactors, by Du Pont and General Electric, are underway and two demonstration power reactors requiring enriched fuel are being designed by Westinghouse and Combustion Engineering. The test reactors will contribute importantly, but are primarily aimed at fuel development. No one of the reactors now going forward is a test for natural uranium power operation.

We are not attacking the central problem of operating on natural uranium now.

The AEC has also indicated continued and increased cooperation with Canada. NDA endorses this cooperation with Dr. W. B. Lewis and Atomic Energy of Canada, Ltd. Cooperation with AECL has been effective and productive. We hope that this cooperation with Canada will mean the building of a better prototype reactor in the United States as well as the speeding of heavy-water reactors throughout the free world. Dr. Lewis' 20 megawatt NPD–2 is being built by Canadian General Electric.

Representative HOLIFIELD. May I stop you there to ask this question? As I understand it, we have participated in this study along with possibly some of the nations of Euratom on this Canadian study? Is that right?

Mr. MENKE. My next paragraph speaks of the participation of the Europeans.

Representative HOLIFIELD. I am sorry, I had not read your statement. Will you proceed, please?

Mr. MENKE. A sound basis for a new step forward this year should emerge from the heavy water natural uranium study which you authorized and which Sargent and Lundy and NDA were selected competitively by the Commission to perform. Our reports recommend a power prototype reactor operable on natural uranium and capable of being built with development limited to that which can be accomplished during design and construction. I mean not exotic. This study has been carried forward with the enthusiastic participation off technical representatives from Euratom, OEEC, and Sweden, as well as with the cooperation of Dr. Lewis and his staff. We have observed during recent months a steadily increasing level of interest

in heavy water, natural uranium reactors in Europe. We have received firsthand indications that many European groups would welcome an opportunity to have working participants on the design team for a power prototype built in the United States. They feel that this would speed the time when they could put successor plants in their own programs.

Representative HOLIFIELD. Now, Mr. Chairman, let me try to differentiate in my own mind between the 20 megawatt plant which you say is being built by Canadian General Electric at this time, and what you are advocating here. Will the Canadian plant take the place, prototypewise, of the plant you are advocating here, or is this a different kind of plant?

Mr. MENKE. This is a different plant. It would not take the place of it. The Canadian plant is an earlier type plant.

Representative HOLIFIELD. An earlier? A smaller one?

Mr. MENKE. Yes, 20 megawatts. The one we will recommend and have transmitted to the Commission is a 70 megawatt plant to meet head on the problem of operation with natural uranium.

Representative HOLIFIELD. Why do you say that a 70 megawatt plant is necessary? I am speaking completely from a technological standpoint. Would it prove something that you cannot prove in a 20 megawatt size?

Mr. MENKE. The burnup properties of such a reactor on natural uranium. That is is what it would prove.

Representative HOLIFIELD. In other words, you are up against the same problem that you were in Shippingport. You had to have a larger size plant in order to get the experience of burnup and the flux necessary in a mass quantity of fuel elements.

Mr. MENKE. That is exactly correct. The central question in a natural uranium reactor is how much reactivity is there to burn. This question is not being attacked in an adequate manner in the United States or anywhere else in the world.

Representative HOLIFIELD. Are there any other basically important technological facts which could be gained by a larger size, like the 70 megawatt, as cotradistinct from the 20 megawatt?

Mr. MENKE. The reactivity question is the central question. I am trying to think if there are others. I think that is the central question. Whether the reactor will operate stably and for a long term and to a high burnup on natural uranium.

Mr. RAMEY. There are differences also as to the time element. I mean the question of boiling, for example, in your pressure tubes.

Mr. MENKE. I had refrained from dealing with the substance of this report in my presentation to the committee because the Atomic Energy Commission, in my opinion, is entitled to receive the report and comment on it. I am sensitive to their having this opportunity.

Representative HOLIFIELD. I would not want you to answer anything that you consider unethical in view of your contractual relationship with the AEC.

Chairman ANDERSON. We will let you come back at a later date and give us some information on that, or we may write you to supply an additional statement. We are anxious to find out if a second type

needs to be built or if a Canadian 20 megawatt satisfies all the requirements in this field of heavy water natural uranium reactor.

Mr. MENKE. I only wanted to explain why I had not done this before. I think it is not unreasonable for you to have the information which Mr. Ramey asks, because you did authorize the study. The reactor which is recommended is cooled by boiling, which is an advance which has been made in this country. It is not an exotic one, as I indicated before. That is a difference which saves a good deal of money and according to our studies it reduces the cost of power.

Representative HOLIFIELD. I am not insisting on any further answers, but I agree with you that the Congress did authorize and furnish the money for the studies and of course they will in due time receive the report and we respect the intervening steps that have to be taken.

Mr. MENKE. I have indicated that heavy water reactors operable on natural uranium are important to national security, technically feasible, and important to develop as an element of U.S. engineering leadership. We should all be interested in asking another question. Are heavy water reactors operable on natural uranium in prospect of being economically competitive?

The demonstration prototype which should be authorized this year for construction in the United States in cooperation with Canada and our friends abroad will, of course, not produce economically competitive power. It is too small. As you will see in our reports on the heavy water study, it is possible to get on now with a prototype which is in the evolutionary path toward economically very attractive powerplants. The future potential of these systems is at least as promising as any now being developed. This is a fundamentally sound direction.

Heavy water is a fundamentally sound direction for you to have asked for progress in.

In summary, let me again urge the importance of natural uranium, heavy water reactors for our national policy, and the desirability of proceeding vigorously now with a small SDR reactor experiment and with the larger heavy water natural uranium prototype power reactor.

Chairman ANDERSON. Thank you very much. It is interesting that the future potential of these systems is as promising as any now being developed is right along the line that this committee has been saying, that we need to have a rather complete examination of many promising types. This is very encouraging. Are there any questions?

Representative HOSMER. I would like to take about 30 seconds to tell Mr. Menke that I have the greatest admiration for him and his associates, and when I used the term "dog" a while ago, I had no reference at all to their splendid work.

Chairman ANDERSON. I am sure he was barking up the wrong tree. Are there any additional questions? If not, thank you very much. I know Mr. Hosmer well enough to know what he says is true, that he had no reference to you, and I am quite sure of it.

Mr. MENKE. Thank you.

STATEMENT OF JEROME D. LUNTZ, EDITOR AND ASSOCIATE PUBLISHER, NUCLEONICS, McGRAW-HILL PUBLISHING CO., INC., NEW YORK

Mr. LUNTZ. Mr. Chairman, I appreciate your kind invitation to me to appear at these hearings.

I would like to comment on several matters that the committee has indicated an interest in.

In my appearances before the committee in the past several years, I have expressed my feelings on the importance of establishing clear-cut goals for our program, and for increasing the vigor of our domestic- and foreign-oriented efforts.

Such clear-cut goals have now been established in the sense that the committee, the Commission, and AEC's ad hoc advisory committee have suggested somewhat similar objectives. These objectives call for a very strong U.S. nuclear power program both at home and abroad.

In the past year, the United States has taken a major step that should assure our leadership abroad in the eyes of other countries. I have reference to the very bold and ambitious joint U.S.-Euratom program that calls for the building in Western Europe of 1 million kilowatts of nuclear-power-plant capacity in the next several years. This program will accomplish four things, I believe. First, the mere building abroad of the largest amount of nuclear capacity yet exported by any country will bring the United States considerable prestige. Second, we shall be giving invaluable assistance to our friends. Third, we shall be getting the benefit of technology and experience on an appreciable number of full-scale second-to-third generation water reactors, presumably of both the pressurized and boiling types. And fourth, American industry will have the opportunity to participate in a substantial amount of business.

Apparently, the Commission intends to extend some of the features of the Euratom support program to other countries. This should further strengthen American leadership in the atomic energy field.

Our activities in the Euratom program and other parts of the world should permit us to concentrate our energies at home on pressing ahead with the development of the technology that will hasten the day of competitive nuclear power. I feel that the mere fact that the U.S.S.R., for example, may be building plants of a particular size or number should not force us to match them in either size or number.

The task we have now is to pursue with vigor the most interesting lines of development. The ad hoc committee pointed out one of these lines when it said:

> We believe that within the next 4 to 6 years experience with boiling water and pressurized water reactors will show how such reactors might be built to produce power that will be economically competitive or nearly so.

This is a most encouraging statement and suggests that strong emphasis here will bring early fruits.

Basically, after all the discussion over the past several years on what we should be building, I feel there's really very little disagreement on the matter of types to be built.

A main point of controversy still appears to be the matter of who should do the building. The most important thing to me is to get

on with the job, regardless of who does the building. I have always felt that if responsible industrial organizations want to put substantial money into building experimental, prototype, or full-scale reactors either on their own or on some sort of partnership basis with AEC, then the Government should welcome this. A not-too-long time limit of something like 90 days could be imposed on industry for submission of proposals under joint programs.

However, if it is necessary to do so to overcome the controversy, I certainly see no objection to having AEC build first-generation reactors under certain ground rules. In this connection, I fully support the program that Senator Anderson proposes in his article in the current issue of Nucleonics.

On the matter of the ground rules mentioned above under which AEC should build first-generation reactors, I would like to refer to an editorial published in the February issue of Nucleonics entitled "Let's Eliminate the Public Versus Private Power Issue." I would like to expand on and amend certain of the suggestions listed there.

Basically, I feel that regardless of what any one individual feels about the existence of the "public-private" issue, the fact remains that there are an appreciable number of people who continue to believe that this issue has existed and still exists. Thus if the issue can be eliminated by legislative means, then I believe that much of the controversy that we've had in this field can be eliminated. I suppose that a test of whether or not there is an issue would be the ease or difficulty of coming to agreement on how to eliminate the issue.

Basic to eliminating the issue would be agreement that the AEC and the Atomic Energy Act of 1954 would not be used to change the balance between public and private power in the United States. Perhaps something to this effect could even be written into the law.

Additional suggestions (in the form of amendments to the act) for eliminating the issue are as follows (these are modifications of my earlier proposals):

1. All electricity-producing experimental and prototype nuclear power reactors paid for in entirety by AEC shall be built at existing AEC sites, except for such plants as might be covered by an extension of the second-round demonstration program.

2. AEC shall only build first generation experimental and prototype power reactors, unless AEC determines that certain later generation reactors are required and that no industrial interest can be found in building such reactors.

3. At any one time, the electricity produced from nuclear reactors at an AEC site shall not exceed the electric power requirements of that site. This may require that at any one time not all experimental power reactors in operation will have generators connected.

My interest in suggesting these amendments to the law, as I've said previously, is to help us get on with the job. I am not trying to promote the interests of one group over another. Amendments such as these would require compromises on both sides, compromises that I believe would not seriously interfere with the activities of either.

I would like to add here a plea. It is important for this country's nuclear power effort to move ahead. To do this we need a harmonious working relationship between the legislative and executive branches concerned with atomic energy. I feel that if we take into account

such excellent studies as that of the AEC's ad hoc committee, the membership of which includes a cross section of our national interests, we would see that we are not very far apart. As a private citizen I do hope that every effort will be made by all parties involved to work out an amicable solution.

These are all the comments I have. Thank you again, Mr. Chairman, for the privilege of appearing before your important committee.

Chairman ANDERSON. Thank you, Mr. Luntz. I saw these three proposals for amendments and I just asked Mr. Ramey if that is not about what we have been doing. Would you comment on that, Mr. Ramey?

Mr. RAMEY. This is with reference to your proposal No. 1 that electricity producing experimental prototype reactors be built at existing AEC sites, except for the second round. In the committee's version of the accelerated program that was reported out in 1956, it did have language to that effect.

Then in the authorization bill for fiscal year 1957 and 1958, and the current one, for reactor prototypes authorized for AEC construction, that same language is in the law as it now stands. It has been the consistent position that these would be built at AEC sites and that power be absorbed at those sites in connection with the grid at the site.

On No. 2, certainly Senator Anderson in his recommendations, and Mr. Durham, the former chairman, have always said that what the Commission should be doing was to be building these so-called experimental prototypes or first generation reactors and that on others, the better established concepts, that you give private industry a shot at them first, with reasonable time to build them. This was also contained in the Joint Committee staff report that was commented on by industry generally favorably. (Joint Committee Print "Proposed Expanded Civilian Nuclear Power Program", August 1958.)

The third point, that the reactor's production not exceed the power requirements of the site, that is included in the language of the provisions I mentioned. It states that all power will be absorbed in connection with the installation, meaning that it goes into the grid for that installation. It is also, of course, understood, as discussed many times, that the only reason you are producing power is not to be making power as such, but to derive operating experience. What you are trying to produce essentially is technological information. Sometimes you don't necessarily even put any power on. Other times you may want to have continuous runs of a complete powerplant. It all depends on the particular reactor prototype that you are authorizing.

Chairman ANDERSON. I wanted him to make those comments, Mr. Luntz, because I certainly agree with you that if we could possibly get rid of this public versus private power issue for a while and spend our time just developing reactors of the highest possible efficiency in this country, we would be very much better off.

Mr. LUNTZ. May I say, Mr. Chairman, that I have been aware of the specific legislative proposals that Mr. Ramey mentioned. I think the committee and the staff are to be commended for having taken this position in the past. A basic thing that I am trying to get at in these several recommendations, and in the previous one about actually writing into the law the statement that would indicate that the intent

of the act was not to be used to change the balance between public and private power in the country, is that nothing could be more clear than the actual incorporation in the basic act of these points, and not to have to depend upon the implementation on an individual project by project basis. I think it is a matter of trying to go as far as one can go in establishing a favorable environment, which is really what I am seeking here.

Representative HOLIFIELD. I would like to ask you how many times the members of this committee are going to have to repeat the fact that their goal is an economic kilowatt and not the adding of public power to the public power part of the system. How many times do we have to say in speeches time after time that we are perfectly willing to leave the so-called 80–20 formula that may exist at the present time between privately owned power and public power, to overcome this unfounded charge that members of this committee have tried to use this to advance public power projects. How many times do we have to say that?

Mr. LUNTZ. First let me make it clear, Mr. Holifield, that I am not so charging any member of the committee with that intention. I think perhaps one answer is that if this were done legislatively, it would not be necessary to be done again.

Representative HOLIFIELD. We have tried to do it legislatively as the staff has read to you there out of reports and out of provisions of the law. For instance, the Gore-Holifield bill sought to do exactly what you outline there in your poposition No. 1. This was passed by the Senate and it failed by a few votes in the House. This I think was about 3 years ago. It specifically specified that large-scale reactors would be built on Government sites and that the resulting electricity would be used by Government at atomic energy sites. This was the great bill which everyone threw up their hands at, including the Commission, and labeled this committee as being an advocate of public power.

Representative DURHAM. Will the gentleman yield at that point?

Representative HOLIFIELD. Yes; I yield.

Representative DURHAM. I think that is exactly correct. We at no time have brought this into focus. It has been brought in here by individuals and by groups that at the present time are not qualified financially to carry out the obligation under the formula laid down for the whole field of the development of atomic energy, as I see it. Why it gets in here, I don't know, but it is continually in here.

Representative HOLIFIELD. I make the charge that it has been introduced deliberately by members of the Atomic Energy Commission and by public speakers in the private utilities for the purpose of dragging a red herring across the trail of getting on with the development of prototypes in the field. The thing we have said continuously, as was testified by the previous witness, when technology gets to the point where a prototype is needed and is generally accepted by the scientific community that it is in order, then we have said if private enterprise will not build it, then the Government should build it. For what purpose? To get on with the art. Just as we built Shippingport to get on with the art, and turn over electricity to the Duquesne Power & Light, or turn over to them at or near the conventional thermal kilowatt price.

The purpose of building Shippingport was not to create a goal of 2 billion kilowatts. That was not the purpose. The kilowatt production was incidental to the building of a full-scale plant, and the operation of it under operating conditions. The fact that Dusquesne Light & Power, which is a private company, got this number of kilowatts was not considered by us as a matter of importance, any more than Consumers of Nebraska when they get theirs, or Piqua. The thing to do is to get on with this technology. This is what this committee in its entirety has always advocated. Some of us get pretty tired of being put in a false position either by members of the Commission or by public speakers from the private utilities. I just want to express my indignation at this time.

At the bottom of page 2, where you say the main point of controversy still appears to be the matter of who should do the building, the most important thing is to get on with the job, regardless of who does the building. I have always felt that if responsible industrial organizations want to put some money into building experimental full-scale prototype reactors either on their own or some partnership with the AEC, the Government should welcome it. Haven't we always welcomed it? Have we ever turned down any private company that wanted to put some money on the line? We accepted every bona fide proposal.

Representative PRICE. Everyone that has been brought up by the Commission.

Representative HOLIFIELD. Every one was accepted. We accepted some proposals that did not look very good because we wanted to go on with the program. We provided $7 million for the Pennsylvania Power & Light. Some had great doubts about it, but we didn't want to be accused of blocking the art. I think the record of this committee is pretty clear. I have read some of your editorials. I am glad to see that you are finally recognizing in this statement today the position the committee has had all along. I compliment you on your astuteness in finally realizing the position of the committee.

Mr. LUNTZ. I believe, Mr. Holifield, that I have been aware of the position of the committee over the years because I have tried to follow it rather closely. I would like to emphasize that I certainly agree with the intent that you indicated that the committee has as you have just expressed it.

Representative HOLIFIELD. I have expressed this many times in public speeches before.

Mr. LUNTZ. What I am merely trying to do here and perhaps this is a naive hope, is to suggest an additional step that might be taken to improve the environment. The intent of the committee has certainly been clear from these individual actions.

Representative HOLIFIELD. You might be able to use your trade magazine, Nucleonics, which is a very fine magazine—I read it with a great deal of interest, sometimes not entirely in agreement—to dispel some of the fog that has been unnecessarily raised, and to clarify the situation. Maybe they will believe it if they read it in your magazine. They don't believe it if we say it in the committee or on the floor of the House. Maybe they will believe it if you print it in your magazine.

Mr. LUNTZ. I believe in fact if you were to go back over the past issues, you would see an expression of the same philosophy.

Representative DURHAM. In reading the magazine which I follow pretty closely, I gather from your statement today that this public-private power issue was involved here in the committee. I don't think we have ever raised the issue. We fought against it at all times. I have been on this committee since it was first formed and since the 1954 act, when we changed the whole procedure. The committee began then to try to eliminate this idea, knowing the expense of this. We fought against it. Here it bobs up every time we have the 202 hearings. I just don't believe it exists as far as this committee is concerned.

Representative PRICE. It has usually reared its ugly head after the committee reported out bills to accelerate the reactor program. Efforts have been made on the floor to kill these programs by the false issues of public versus private power. That is where the issue usually raises its ugly head, by those who want to stop an accelerated program.

Mr. LUNTZ. I think there are extremists at both ends. Those who would like to see 100 percent private power, and those who would like to see 100 percent public power.

Representative PRICE. Those of us who have always been for the acceleration of the nuclear program have never at any time been involved in either the public or private power end of a debate. I say that this has always been true.

Representative HOLIFIELD. I want to ask you one question.

Representative DURHAM. I would say to the gentleman from Illinois, we have stuck strictly to the research and development of this. Having some knowledge of the cost of trying to integrate it into a system which at the present time produces power at a cheaper cost than we can do it out of the atom yet. That has been our main purpose in this whole situation.

Representative HOLIFIELD. In your reference to the Euratom program, do you believe that each of these projects in Euratom should be approved by this committee on the basis of technological advance, and that we should not approve projects which might be termed replicas of existing technology whether it be in England or in the United States just for the purpose of producing kilowatts, taking into consideration the fact the taxpayers' money may be invested in this in loans and grants in free fuel and free water and one thing and another up to the tune of $500 million or $600 million before we get out of it. I am not talking about this additional offer of $50 million worth of enriched fuel which may go outside of Euratom. I am talking about the Euratom program itself. If my question is not clear——

Mr. LUNTZ. No; it is clear, Mr. Holifield. I think that basically depends on what you mean by advancing the art. My own feeling on this, I think, is expressed in the words up at the very top of page 2 where it is my assumption that the reactors that will be built will be what I would call second to third generation reactors. They would lie somewhere in between probably because of the time scale. I don't know whether you would interpret that to represent an advance in the art. Certainly it is an advance over the present situation, so in that sense it is moving ahead.

Representative HOLIFIELD. I would say that full-scale second to third generation power reactors, if they were larger and if they included technological advances, higher temperatures, and things of that sort, would be an advance in the art. I would not say that if you build duplicates of the Calder Hall reactors, for instance, that are now in existence, or any reactors that might be in existence in this country, such as, let us say, Commonwealth Edison or General Electric's reactors, or any other reactor—I just happened to think of them because they will be on the line sooner than any others and probably sooner than most of these that we have not gotten along very far with in Europe. I would not think that we would be justified in putting American taxpayers' money into those reactors just in order to build an atomic reactor to produce power in Europe.

Mr. LUNTZ. I would agree with you, sir.

Representative HOLIFIELD. There should be some advancement in the art.

Mr. LUNTZ. In my appearance before the committee 2 years ago, I made the recommendation that there be a foreign power demonstration program similar in type to the domestic demonstration program with the idea in mind that we would use that program to build reactors in countries that had a greater need for nuclear power today than the United States did, and that the benefit therefrom would be, among other things, advance in the technology. So I am in full sympathy with your feelings on that.

Representative HOLIFIELD. I would not want the record closed without me saying that the Euratom authorization language which we passed did not confine the type of reactor to pressurized and boiling-water types, but that it included language which could justify any other type of reactor in which there was a scientific breakthrough, you might say, or a possibility of it being more desirable. For example, the organic reactor, or even this new proposal, which is still as far as I am concerned in the realm of theory, if suddenly we could prove that the new General Dynamics proposal was feasible and practical. If we could get to the point of proof on it. I don't think we can. When I say I don't think we can, I mean within the time limit that might apply to Euratom. I am not saying that we won't get to it some day. The heavy-water type which has shown great promise. This would also have to be done on substantial scientific support. I would not want to add an exotic type just because somebody thought it might work.

Mr. LUNTZ. The time scale for submission of proposals, where bids are due September 1 of this year, is such that it would presumably preclude certain advanced types.

Representative HOLIFIELD. There is a 2-year stagger, you remember.

Mr. LUNTZ. Yes. I am thinking of the program that would be implemented in 1959.

Representative HOLIFIELD. We foresaw this potential eventuality, and we did put in the extension of time for 2 additional years.

Mr. RAMEY. For two reactors. Under the ground rules an outfit has until October 1 to indicate an interest in submitting a proposal for a reactor to be built on the longer time scale so that the Commission can consider that type of reactor at the same time it is considering the more established types of technology.

Representative DURHAM. I think the precaution we took in writing the act—I had the same fears that the gentleman from California has had—was that we might oversell ourselves and get ourselves into a situation so that we would not accomplish what we really desired. I have great faith in this Euratom development. After all, we have to sit here in a more or less judgment seat finally. So I hope we won't make mistakes and disappoint people. That is the precaution we tried to take in writing the act. I think we went as far as we could go. I know the gentleman from California had great concern, and so did the rest of us, that we did not want to get into something here that would disappoint the whole world.

For the last few days they have been over here, and I had quite a considerable conversation with them yesterday and today. I think they are approaching this thing on a very sound basis, if they continue to use caution and not accept some sale that we sometime promote on our Washington birthday sales, and buying something that is probably of no use to them in their program.

Are there any other questions? If not, thank you very much, Mr. Luntz. We always enjoy having you here.

Mr. LUNTZ. Thank you very much, Mr. Durham.

Representative DURHAM. The next witness is Mr. Ray McBrian, director of research, Denver & Rio Grande Western Railroad Co.

STATEMENT OF RAY McBRIAN, DIRECTOR OF RESEARCH, DENVER & RIO GRANDE WESTERN RAILROAD CO.

Mr. MCBRIAN. Mr. Chairman, members of the committee, this testimony is given with the objective that the committee gain better understanding of the applications, present and future, of atomic energy to the railroad industry, and other peacetime applications.

The first question that I would like to discuss is "Can the railroads use atomic energy in any form as a source of power?" My answer is, we will not know until a thorough research effort has been made to determine the specific possibilities for railroad application. It is not satisfactory to state that because of "safety and health" hazards and legal requirements, no moving unit can ever be successful in a railroad application. These problems, while admittedly formidable, are not insurmountable. If the committee overlooks the railroad industry as a possible consumer of atomic power, the following inconsistency in policy will result.

A primary objective of the nuclear power program is to reduce the cost of nuclear power to levels competitive with power from fossil fuels in high energy cost areas of this country in the near future. The railroad industry, on whose locomotives is 15 percent of the installed electrical capacity in the United States, is the largest producer of high energy cost power.

To say that atomic energy has no use as railroad power because of a safety question is just as absurd as saying that atomic energy has no use in central station powerplants because of an economic question. Sufficient research can probably solve both problems.

In other areas of the world, atomic railroad propulsion is being seriously considered. I have a translation of an article from a Russian

technical journal which describes research programs being carried out at the Bauman Institute in Moscow.

I wish to submit this detail as a part of my record.

Representative DURHAM. Without objection it will be included in the record. I think it is well to have it.

(The information referred to follows:)

A LOCOMOTIVE FOR USE IN THE DESERTS, ON THE LONG HAUL, AND IN MOUNTAIN PASSES

The steam locomotive, which produced a revolution in transportation and has already served mankind faithfully for more than 120 years, is now being supplanted by incomparably more economical and more powerful locomotives—diesel, gas turbine, and electric. However, in the future it is possible that these locomotives may also relinquish their place to a more advanced type of transportation on the longest trunk railroad lines.

Atomic locomotive designs are being developed with a view toward using this type of engine installation at the earliest opportunity.

In particular, the locomotive-building chair of the Moscow Technical College (The Bauman Institute) has worked out a project for an atomic steam turbine freight locomotive with electric drive (illustration 5). Its capacity is 5,500 horsepower (approximately the same capacity as for one of our most powerful electric locomotives—the type N–8). It is designed for use on track of conventional gage—1 meter 524 millimeters.

The locomotive is to consist of two sections with an overall length of 50 meters. The first section will contain the reactor and heat exchangers (steam generators). The turbine and condenser will be located in the second section. The entire powerplant will weigh about 200 (metric) tons, and the total weight of the locomotive will be 430 (metric) tons. The locomotive will have 12 driving axles, each of which is turned by an electric motor of about 360 kilowatts power.

In trying to build a more economical atomic installation, the designers decided on a graphite-uranium reactor. For fuel, as in the case of the first atomic electric station, uranium enriched up to 5 percent with uranium 235 is employed. The cylindrical active section of the reactor is 2 meters high and has a diameter of 1.5 meters. Also placed here are 1.5 (metric) tons of uranium and almost 7 (metric) tons of retarder.

This section is surrounded by a graphite reflector, and the entire reactor is enclosed by a shield made of layers of lead and reinforced concrete. Tubes containing metallic uranium rods pass through inside the reactor's graphite blocks. Flowing through the space between the tubes and the rods is a heat-transfer agent—liquid sodium. With its help, heat is carried away from the active section. The pressure in the reactor is about 3.5 atmospheres. The calculated temperature in the center of the reactor will reach 500° C. The sodium, heated to 450° C., is directed by special pumps into the primary heat exchanger, which is clad in a layer of concrete 80 centimeters thick. Here it delivers its heat to yet another intermediate heat-transfer agent. Liquid sodium is also used here. The radioactivity of the secondary heat-transfer agent is not great. Therefore, it is possible to feed it into the steam generator without being afraid that it will be contaminated by radioactivity.

From the steam generator, superheated steam at a temperature of 400° C., and a pressure of 80 atmospheres enters the turbine, which turns several electric generators. From the generator the current is fed to the electric motors which are connected to the locomotive axles. Beyond the turbine, the steam in the condenser is converted into water which again returns to the steam generator.

Despite its use of steam, the atomic locomotive can cover a distance of 1,000 kilometers without replenishing its water.

We mentioned previously that liquid sodium is pumped into the main pipes of the locomotive's powerplant by special pumps. More and more use is now being made of new-type, electromagnetic pumps to pump liquid metals. The expediency of using these pumps is explained by the fact that they do not have rotating parts; they are able to work at the high temperature of the metal being transferred; they create the necessary pressure; and they are absolutely hermetic. The latter is especially important for atomic powerplants, where leakage of negligible quantities of radioactive substances is dangerous.

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The simplest pump of this type, which operates on direct current, consists of a flat chamber to which the pipes of the circulating system are soldered. The chamber is located across a uniform magnetic field. In addition, electrodes are welded onto it from two sides. In order to avoid a short circuit through the metal being pumped, the chamber is made of an alloy which has a naturally high electrical resistance. Depending on the direction of the current and the location of the poles of the magnet, the liquid metal will move in one or the other direction along the pipes leading to the chamber. The direction of transfer of the metal can be established according to the well-known left-hand rule. A pump of this type can insure feeding of the liquid metal at a pressure on the order of 4 atmospheres and an efficiency equal to about 50 percent.

Another kind of pump—the induction type—uses alternating current. We will assume that instead of the armature of an electric motor, a fixed, guiding, spiral surface enclosed in a pipe and filled with liquid metal is placed inside the stator. The rotating magnetic field of the stator, interacting with the induction currents in the metal, forces the metal to circulate. Moving along the spiral surface, it will enter the system. There are known pumps of this type which pump up to 20 liters of metal per second at a pressure of about 8 atmospheres and with comparatively high efficiency—up to 80 percent.

Electromagnetic flow meters are widely used to measure the deliveries of electric-conducting liquids including molten metals. They rather resemble an inverted pump. According to the velocity of the metal flowing through the flat chamber located in a magnetic field, an electromotive force is created on its bus bars. This electromotive force is delivered to a precalibrated instrument which shows the delivery of the metal.

An instrument of this type, connected through an amplifier and relay with a valve of the main pipe, can automatically regulate the delivery of liquid.

High requirements are also made on the piping system for nuclear powerplants, especially on pipes through which radioactive liquids flows. As with the pumps, such piping must be absolutely hermetic. Only thick-walled, seamless pipe is authorized for use. The material from which this pipe is made (usually stainless steel) must possess high anticorrosion qualities and must not enter into a chemical reaction with the substances passing through the pipe.

The pipe walls must withstand scouring well since the liquids flowing through can carry washed-off particles to places where the speed of flow is less (valves, filters, etc.). Here the particles precipitate and can cause the system to clog up. The joints at the junctions of the main pipelines are welded in an inert gas medium and are checked with special care. It is also desirable that the system have a minimum number of separable connections. When such connections are necessary for operational convenience, they must be made in a safe manner.

The locomotive's protective shield is especially reinforced in the front part of the locomotive where the engineer's cab is located. Here the thickness of the reinforced concrete wall reaches 2.5 meters. Excellent visibility of the railroad track will be provided from the cab. Control of the atomic locomotive is achieved with the help of a telemechanical device. On the control panel are two main handles. One is for regulating the operating regime of the reactor and the feeding of steam. The other is to control the braking action. Also located here on the control panel is an illuminated layout of the locomotive's powerplant: electric bulbs of different colors will signal the smallest deviation from the powerplant's normal operating regime. Elimination of these troubles by means of an automatic device without participation by the engineer is possible. The locomotive may be equipped with a radio receiver and transmitter, an automatic train stop, and a television unit.

The atomic locomotive will pull a train weighing 4,000 (metric) tons at a speed up to 90 kilometers per hour. How long will the atomic locomotive be able to operate without another charge of fuel? A day? A week, A month?

The principal virtue of the locomotive is that its reactor would be able to operate continuously for 7,200 hours—300 days, or almost a year. Fuel consumption for such a locomotive will come to not more than 10 grams per 1,000 kilometers of travel. Thus, in order to take a train from Moscow to Riga and return, a piece of fuel no bigger than a hazel nut would be required.

Other plans for atomic locomotives are also in existence. For example, an atomic steam turbine locomotive weighing about 360 (metric) tons has been designed (illustration 6). Its length, together with trailer, is about 50 meters; and its height is about 5 meters. Track gage on which this locomotive would operate is 3 meters, which somewhat exceeds the conventional gage for railroad

lines. Therefore, special main railroad lines would have to be built for such an atomic locomotive.

In this locomotive, plans call for installation of a homogeneous reactor which has a hexahedral shape and is welded from stainless steel plate. It will be enclosed by a biological shield weighing 100 (metric) tons and having a thickness of 1.2 meters. The reactor would be charged with a solution of uranium salt in water containing 9 kilograms of uranium 235.

Distilled water will be fed through the reactor by thin-walled tubes: in these tubes the water is evaporated and changes into superheated steam, which goes into the turbine.

Formation of heat in the reactor and, consequently, its power as well, is regulated by rods made of special steel which contains boron and cadmium, The estimated heat output of the reactor is about 30,000 kilowatts.

It is estimated that the steam, which enters the turbine with a power of about 8,000 horsepower, will have a pressure of 12 atmospheres and a temperature of 200° (Centigrade). The depleted steam is directed into the condenser tubes, which are washed by cold water from radiators located in the trailer (tender). The steam is condensed and, having formed water, is returned into the reactor's system. Thus it is admitted beforehand that the locomotive's turbine will operate on radioactive steam. Therefore, difficulties are inevitable even with regard to the most insignificant repair of a turbine contaminated by radioactive elements. That is why the locomotive version designed in the Moscow Technical College may be more suitable in operational use despite the fact that it is somewhat heavier because it uses two contours (circuits) with a sodium heat transfer agent.

The turbine of the described atomic locomotive turns four electric generators. The direct current from them goes to 12 electric traction motors, each with a capacity of 600 horsepower. The reactor-filling water containing dissolved uranyl sulfate will, at high temperature in an exposure field, be partially broken down into hydrogen and oxygen. The gaseous hydrogen and oxygen, in rising, will carry along water particles after it. A special rotating vane wheel of the separator will throw the water droplets down into the reactor, and a dry, fulminating mixture of hydrogen and oxygen will be sent into an auxiliary turbine and then will go into a catalyzing chamber. Here the hydrogen and oxygen are again converted into water, which is returned to the reactor.

This auxiliary line can insure feeding the turbine with an output of 1,000 horsepower, which turns the generator that generates current for driving the locomotive's auxiliary mechanisms.

A number of specialists believe that the reactor of this locomotive, being filled with a solution of nuclear fuel, is especially dangerous in case of an accident, which might cause a stoppage of movement over the railroad line during the time required for decontamination and removal of radioactive parts. Therefore, serious precautionary measures must be taken to prevent accidents involving atomic locomotives.

Several days each year will be required under normal operating conditions to charge a locomotive's reactor with a fuel mixture. During this time it is necessary to add about 5 kilograms of uranium 235 into the reactor. It is estimated that after one recharging of the reactor, the locomotive will be able to run more than 80,000 kilometers, that is, it could go around the earth twice at the equator.

There are also designs for several lighter atomic locomotives of the gas turbine type. According to one of these designs, the locomotive will have two 3-axle trailers (tenders) with an overall weight of about 180 (metric) tons and a total weight of 38.5 (metric) tons for the protective shield. It is proposed that an air compressor be installed in the locomotive.

This compressor must be extremely powerful and will consist of several series-arranged wheels with blades. The compressor will force air through the reactor, which has a heat output of 15,000 kilowatts. Here the air is heated to a temperature of 700–800° C., then enters a turbine with a capacity of 3,000 horsepower, and is ejected into the atmosphere. The atomic engine's turbine turns electric generators which generate current for 6 electric traction motors of 50 horsepower each. The efficiency of this atomic locomotive is about 18 percent. One of the reasons preventing construction of such a "lighter-weight" atomic gas turbine locomotive is that when it is used in populated areas there arises some danger of radioactive contamination of the air and of places close to the railroad line. It will be necessary to develop special equipment to clean the air of radioactive impurities before it is thrown out into the atmosphere.

We should also mention the imaginative locomotive proposed by the German designer N. Gozla. He suggests that gaseous helium be used as the heat transfer agent and working substance in the closed system of the locomotives' powerplant. A compressor would deliver the helium to the reactor, from which the hot helium would go into the turbine. Then, going through a cooler blown by air fans, it will be returned to the reactor by a compressor. The turbine through hydromechanical transmission will set the wheel axles in rotation. The estimated weight of the locomotive is 175 (metric) tons, length is 35 meters, and capacity is 6,000 horsepower. This is one of the most promising designs.

All of the atomic locomotives about which we have spoken represent a powerful transportation medium. Placed among steam engines, they would look like mammoths among elephants—but they would be mammoths which "eat hardly anything and drink very little." At the present time, the Soviet Unions' railroad transportation consumes about one-fourth of the entire, huge quantity of fuel extracted in our country. Frequently it is necessary to haul the fuel several thousand kilometers. It is true that by 1970, according to the 15-year plan for railroad electrification, up to 60 percent of all rail transportation in the U.S.S.R. will be done by electric locomotives, which will permit the saving of up to 90 million (metric) tons of coal annually.

It may be hoped that on important main railroads which run far beyond electric transmission lines and centers of extracting chemical fuel, atomic locomotives will also permit conserving (this fuel) for other branches of the national economy (illustration 7). With atomic locomotives, the need for building and maintaining vast stores of fuel is removed. The system of water supply stations can be reduced to about one-tenth. The number of personnel required to service and repair locomotives would be cut in half.

Naturally, atomic locomotives will be able to pull heavy trains great distances. They will permit increasing the traffic capacity of main railroad lines by 50 to 70 percent as compared with steam locomotives. The great power of an atomic locomotive would also allow a 60 to 70 percent increase in the weight of the trains.

It is difficult to overestimate the significance of this new type of locomotive for our country. The length of railroad lines in the Soviet Union is three times the length of the equator, and from the standpoint of freight traffic the U.S.S.R.'s railroad transport occupies first place in the world.

Mr. McBRIAN. I might emphasize this one particular part:

The steam locomotive, which has produced a revolution in transportation, has already served mankind faithfully for more than 120 years, has largely been and is now being supplanted by incomparably more economical and more powerful diesels, gas turbines, and electric locomotives. However, in the near future it is possible that these locomotives may also relinquish their place to a more advanced type. Atomic locomotive designs are being developed with a view toward using this type of engine application in Russia at the earliest possible opportunity.

The article continues with a description of several locomotive designs.

Representative VAN ZANDT. How recent is the article?

Mr. McBRIAN. I secured this translation in the last few months. There was no date on the translation. It is very recent.

Mr. RAMEY. Would the Russians have an incentive to develop locomotives from the standpoint of atomic energy because of their vast undeveloped areas in Siberia and China, without population problems and so on?

Mr. McBRIAN. In their statement it is said:

It may be hoped that on the more important mainline railroads which run far beyond electric transmission lines and in the center of extracting chemical fuels atomic motors will permit conserving this fuel for other branches of the national economy, with atomic locomotives in need of building and maintaining large systems, the system of water stations can be reduced to about one-tenth, the number of personnel would be cut in half. Naturally atomic locomotives will be able to pull heavier trains greater distances. They will increase the capacity of 20 to 50 percent as compared with the steam locomotives. It would also allow a 60 to 70 percent increase in the weight of the trains. It is difficult to overestimate

that significance of this new type of locomotive for our country. The length of railroad lines in the Soviet Union is three times the length of the equator and from that standpoint of freight traffic, the U.S.S.R. railroad transportation occupies first place in the world.

The Denver & Rio Grande Western Railroad, in cooperation with the Baldwin-Lima-Hamilton Corp., for the last 4 years has been carrying forward a design study for possible locomotive power. While no one system has passed the dual requirements of safety and economy, several have shown promise and are undergoing further study.

Representative VAN ZANDT. Is the Denver & Rio Grande Western Railroad the only railroad participating in this project?

Mr. MCBRIAN. It is.

Representative VAN ZANDT. The Baldwin-Lima-Hamilton Corp. is the only nonrailroad business interested?

Mr. MCBRIAN. It is. May I say that this came about when we made application to the AEC for a permit to make such a study. They recommended that we join with a builder and this builder was recommended under that program.

Representative VAN ZANDT. Is it not true that other railroads have joined together to take a look at the possibility of atomic power for their locomotives?

Mr. MCBRIAN. No, not as a concerted effort.

Representative VAN ZANDT. Thank you.

Mr. MCBRIAN. It is possible, however, that in some areas of the country, the most economical application of atomic power will not be in mobile units. During a recent trip to Europe, I found in Switzerland that Sulzer Bros., diesel manufacturers who have been engaged in the construction of powerplants for more than 100 years and diesel electric locomotives for a number of years, have a nuclear energy department for study as to energy applications in any possible field, be it generating plants, transportation units, both marine and land. One intriguing study is that of a combined nuclear heating and power plant of a 30,000 kilowatts thermal output to be used both for heating a special district and supplying electrical power at the same time.

The complete nuclear heating and power station is to be situated in two underground rock chambers.

The reactor is heavy water moderated and cooled and mostly utilizes natural uranium as a fuel. It uses 18 tons heavy water, bulk of 5 tons of fuel is in natural uranium form, having small number of fuel elements enriched to 1 percent of uranium 235.

Such possibilities for stationary electrical generating plants and for heating could conceivably also be of interest to railroads wherein the question of "moving units" on rail having radiation problems would be confined to specific local sites and electrical energy delivered by either conventional or newly developed transmission systems to electrical locomotives.

In England, studies were being made at one of the largest turbine manufacturers to develop an atomic powered turbine. This, while primarily for marine use, could also be applicable for railroad transportation.

In our country two new nuclear power reactor design concepts were recently announced, which clearly should be a railroad "must" re-

search consideration. One involved the use of thermoelectric materials in the reactor fuel elements to convert the nuclear derived heat directly into electricity.

Another design makes use of an organic moderated fluid bed reactor in which conventional control rods are not necessary and the fuel is in the form of pellets no larger than marbles, floating in oil.

Aside from the power aspect of nuclear energy as applied to railroads, there are other interesting and vital fields for study.

The reason I am bringing this in, as a result of having this contract with the AEC for the study for a railroad unit, the side issues which may come in may be much more important than the power unit itself.

Representative HOLIFIELD. What do you mean by that?

Mr. MCBRIAN. I will go ahead and explain.

Representative HOLIFIELD. Very well.

Mr. MCBRIAN. At the D. & R.G.W. railroad laboratory in Denver, we have made a number of fruitful applications of radioisotopes.

These applications have been the result of information gained in our study for a power energy unit, which illustrates the vital need to make such studies which often result in possible breakthroughs in other fields that would not have occurred normally.

Representative VAN ZANDT. Will you briefly describe the Denver laboratory which houses this atomic research effort?

Mr. MCBRIAN. We have a railroad laboratory engaged in research. We employ a total of 23 persons. We have two nuclear engineers with the necessary laboratory equipment to engage in atomic energy studies.

We have as a source of radiation units a cobalt 60 unit and some neutron units. The cobalt 60 unit is a 500 millicuries source. We have no large unit, no experimental reactors and most of our work that we have done to date we have sent to such places as Brookhaven, Argonne, Cooke Electric and various other places all over the country for our work.

Representative VAN ZANDT. What does it cost you annually?

Mr. MCBRIAN. We have been spending around $100,000 annually for research work that we have been doing in this field alone. At least $100,000 on the locomotive and probably $40,000 to $100,000 on other types of work we have been doing.

Representative VAN ZANDT. Is any portion of the amount Government money?

Mr. MCBRIAN. None whatever. We have not asked for one dime.

Representative HOLIFIELD. You say you send some of your work to Argonne and other places?

Mr. MCBRIAN. That is right.

Representative HOLIFIELD. Is that theoretical studies which you send to them for checking as to the physics and the calculations?

Mr. MCBRIAN. I will give you an example in the next item.

One of the most interesting studies which we have made has been that of the irradiation of coal. We wrote to Brookhaven and said we wanted to have some coal samples irradiated. A reply came back in which they told us they didn't believe we could irradiate coal. Since the piles were made of carbon and were not affected by irradiation, they did not see that any good would come by irradiating coal and that we wouldn't get any results. Since they didn't know what

we were after in our irradiation studies, we insisted they go ahead, which they did, and we paid for the number of hours of irradiation. It is possible that this scope of study might be of a much larger energy source than the possible application of atomic moving railroad power unit. Our coal studies with irradiation have been made with coal ground to 200 mesh and irradiated as such and with coal ground to 200 mesh mixed with oils, making a coal and oil mixture. The total radiation in roentgens varied from 1,800,000 to 24 million. The time of exposure to irradiation varied from a few hours to 24 hours, or 1 day's time. The radiation intensities varied from 250,000 to 1 million roentgens per hour.

We have found that if we used a high volatile coal, the effect of irradiation on the particles of coal, as measured before and after irradiation by use of electron microscope, showed the particle sizes to be tremendously different.

I thought possibly you might be interested in seeing the effect of this on the micrographs of before and after irradiation. Coal when pulverized at 250 mesh under the ordinary light microscope magnified at 750 diameters will look like this. After irradiation, coal breaks up into micron particle sizes at 6,750 diameters to look like this. When you compare that with the ordinary fossil fuels, which are colloidal and of particle sizes of this size, then coal in this size can be burned in internal combustion engines.

Representative DURHAM. Do you get quicker heat or more heat?

Mr. MCBRIAN. No heat whatever. If you will let me go ahead, I will explain the theory.

We have found that if we used a high-volatile coal the effect of irradiation on the particle size of coal, as measured before and after irradiation by use of the electron microscope, showed particle sizes to be tremendously different. The effect of irradiation being to literally split the coal into such particle size that it could be used the same as liquid hydrocarbon fuel.

Rudolph Diesel originally intended to burn powdered coal in his diesels, but was prevented from doing so because he was unable to secure the proper particle size. Generally speaking, the theory is that coal is composed of saturated and unsaturated hydrocarbons, heterocyclic compounds containing oxygen, nitrogen, sulfur, and aromatic compounds. The aromatic compounds are the primary constituents. In general, irradiation will result in degradation of the constituents of coal, resulting in turn in a decreased particle size. These particle sizes, which we are talking about and which we use in a coal and oil mixture, are on the order of ½ to 1 micron size.

Representative HOLIFIELD. Let me ask you to explain to me what you mean by the degradation of the constituents of coal.

Mr. MCBRIAN. You know the action of water getting inside of concrete and freezing and splitting it. By degradation of coal, we mean that the reaction of radiation on the volatile constituents of hydrogen, methane, and so forth, acts the same way when they start to change their compound and literally explode into these particle sizes. Then we can make it similar to a liquid burnable fuel. I thought you might be interested to see a small sample of such fuel. For example, this is—may I bring these up to you?

Representative HOLIFIELD. Surely. I might say this is one of the most interesting pieces of testimony that I think we have received.

Mr. McBRIAN. This is ordinary diesel fuel. This contains 10 percent coal added to this diesel fuel and we have already burned this in small test engines.

Representative HOLIFIELD. Is this in powder coal or liquid?

Mr. McBRIAN. We have to collect it in oil. When we are talking about coal size particles on the order of one twenty-five thousandth to one two-hundred-fifty thousandth of an inch, these could not be stored and have to be collected in oil.

Representative VAN ZANDT. As I understand, you exposed coal to radiation.

Mr. McBRIAN. That is right.

Representative VAN ZANDT. It causes the coal to literally explode.

Mr. McBRIAN. That is right.

Representative VAN ZANDT. Then you mix it with diesel oil?

Mr. McBRIAN. We have done this. We have irradiated the coal separately. We have irradiated with oil and with coal, oil, and a catalyst. This is purely experimental. We don't know why the yield is not up to what we would like; whether it is because of the geometry of the shape of the containers in which the coal is irradiated, or whether we have not ground the coal to the right size, or if we can irradiate coal without grinding it. We now have to determine these facts, and it will take pilot plants to do so. We have burned irradiated coal and oil mixtures in a test engine. We know it will burn satisfactorily.

Representative VAN ZANDT. What about the coal that has been exposed to irradiation and put in the firebox of a locomotive?

Mr. McBRIAN. No, we put it in a diesel engine mixed with diesel fuel.

Representative VAN ZANDT. What do you get in the way of additional heat?

Mr. McBRIAN. No. The B.t.u. value of the coal is the same as the diesel fuel. What we get is economy. In other words, for example, diesel fuel may cost 11 cents a gallon. For every 10 percent of coal we add to this 11-cent diesel fuel, we reduce the price approximately 1 cent. One cent a gallon fuel savings to our railroad means an earning to the stockholders of 20 cents a share.

Representative PRICE. To clarify the record, you have only done this with a small test engine.

Mr. McBRIAN. That is right. This has been only a research project. The reason I am bringing this out is to show the possibilities of future research.

Representative VAN ZANDT. Did I understand the witness to say you get a greater steam pressure?

Mr. McBRIAN. No. We are not using this in coal fired engines. This is in internal combustion engines. You could mix it with gasoline or diesel fuel. What we are trying to do is to reduce the cost of fossil fuels economically. That is what we are trying to do with atomic energy. In other words, on our railroad we believe that it costs us about 25 mills for electrical energy from diesel-electric power units to be delivered to the rail. If we built an atomic powered locomotive, the fuel burnup value of uranium would be equivalent to our securing a five-to-six-cent fossile fuel.

If we can reduce the cost of present fossil fuel by irradiating cheap coal, we may not ever need the atomic powered locomotive other than for reasons of being able to go long times between overhauls and thinks like that and secure other maintenance savings.

Representative DURHAM. You wind up with the same B.t.u. that you get from the diesel oil.

Mr. MCBRIAN. We wind up with the same B.t.u. This can only be done with high volatile coals.

Representative DURHAM. You may proceed.

Mr. MCBRIAN. Since the B.t.u. content of a pound of coal and a pound of fuel oil is about the same, the mixtures of coal and fuel oil in any percentages will result in equivalent values at lower cost and offer the possibilities of the making of a substitute fuel should there be shortages of petroleum products. This research is continuing and through the use of catalysts offers considerably more promise, but it is necessary to have available radiation facilities and other technical information which would speed this research so that large-scale application could be made.

Representative VAN ZANDT. Are you encountering any problems in getting radiation facilities and technical information?

Mr. MCBRIAN. In what respect?

Representative VAN ZANDT. To assist the effort being put forth in the laboratory in Denver.

Mr. MCBRIAN. I can't answer that except in this way: As of 2 weeks ago, the AEC under their new program, suggested the possibility that with their large million curie cobalt source we might wish to join with them and other companies in a joint study. This will have to be explored. Up until that time we did not have any offer of any type.

Representative VAN ZANDT. You are satisfied with the cooperation you are receiving from the AEC?

Mr. MCBRIAN. At the moment we will have to further explore with the AEC to find out just exactly how far we can go with them. We have not as yet asked them to work with us. We want them to work with us and we are going to explore that possibility.

Representative DURHAM. If this turned out to be efficient and satisfactory, it would require large space for irradiation.

Mr. MCBRIAN. Yes. What we have to have is a pilot plant.

Representative HOLIFIELD. Is there any reason why some of this highly radioactive waste material could not be used for quantity type radiation?

Mr. MCBRIAN. In fact, that is what we envision doing. To have radioactive waste material under concrete vaults with conveyor belts. That is why we will probably need AEC's help to build such a plant in order to prove out the theory. The coals are now being irradiated with cobalt 60 sources and neutron sources. We need the use of waste materials.

Representative DURHAM. That would cut your expenses tremendously.

Mr. MCBRIAN. Yes, quite so.

Representative VAN ZANDT. Have you developed any cost data on the ungrading of coal by irradiation to increase its utility?

Mr. MCBRIAN. What was that?

Representative VAN ZANDT. Have you developed any cost data?

Mr. McBRIAN. We have not. This has been purely theoretical and experimental. However, we feel if we could use waste materials and with the building of the concrete facilities with the use of conveyor belts, the cost would be very minor.

Another field in which we are seeking ways and means by irradiation to effect greater savings and usages is to take abundant softwoods and prepare these into equivalent of hardwoods. Our preliminary research studies indicate that it is theoretically possible, by the use of certain chemicals and gamma irradiation, to induce crosslinking or polymerization in softwoods and thereby secure the equivalent of hardwood. Of special interest to the railroads would be the making of a cross tie, and this study would have widespread possibilities in other industries. The irradiation also appears to have the possibility of improving the seasoning of green woods. It will be necessary under such studies to have full access to work already done and to have the cooperation of irradiation and pilotplant facilities. This possible peacetime application offers another use of waste radiation products which might be developed economically into a successful process and application.

Representative VAN ZANDT. Have you tried to gain access to information already developed?

Mr. McBRIAN. We have. The AEC as of 3 weeks ago are digging up all the information which they have available to send us.

Representative VAN ZANDT. Let me ask you a question about a tie already treated with creosote.

Mr. McBRIAN. That is right.

Representative VAN ZANDT. What happens when the treated tie is exposed to irradiation?

Mr. McBRIAN. You are asking a question I did not include here. We have taken creosoted ties and by radiation we drive the depth of creosote deeper into the wood and improve that treatment. What we are proposing here is that where we use fir and oak ties now, we could use soft pines, mix it with chemicals and radiation to harden and so make a cheaper tie than the oak or other materials.

Representative VAN ZANDT. In other words, it would make available other types of wood.

Mr. McBRIAN. That is right.

Representative VAN ZANDT. At the same time a cheaper tie.

Mr. McBRIAN. That is right.

Representative DURHAM. They are going to take soft pine and make it into hardwood.

Mr. McBRIAN. That is right. That is what we are thinking about.

Representative DURHAM. If you do that, you have accomplished something.

Mr. McBRIAN. Another major research project which we on the D. & R.G.W. have is a contract with the U.S. Army Quartermaster Corps, which offers considerable possibilities both to our road and to the railroad industry in general, the major objective of which is twofold. First, to establish optimum conditions whereby fresh perishables may, through irradiation, be conditioned so that they may be shipped across country or for long distances for a period of 20 days or more without the use of refrigeration and at ambient temperatures and without having the deterioration which normally occurs.

Second, to gain knowledge and control of all possible conditions that are necessary for the preservation of fresh perishables through irradiation and packaging techniques which will lead to extended shelf life and prolonged storage periods. This again illustrates another very promising field of research in the atomic energy field.

Representative VAN ZANDT. I can see here elimination of refrigeration. Are you working in that direction?

Mr. MCBRIAN. That is right.

Representative VAN ZANDT. It would be quite a saving to the railroad, would it not?

Mr. MCBRIAN. It would be a considerable saving.

Representative VAN ZANDT. At the same time it would be a saving to the Government.

Mr. MCBRIAN. Yes.

Representative VAN ZANDT. You are working hand in hand with the Government?

Mr. MCBRIAN. Yes; one of the interesting things which I did not include in the report, and I only mention this because we have further research to do, is that by irradiating packaging materials instead of the vegetables or fruits themselves, we have been able with certain types of packaging material to seemingly get results similar to those as with irradiating the vegetable which will do away with any consumer complaint about taste and having the materials directly irradiated. We are now following that conclusion.

Representative VAN ZANDT. You can also eliminate insects from certain types of food.

Mr. MCBRIAN. That is right.

Another possibility for study is that of nuclear cells or batteries. This should be a must project because nuclear cells offer a prospect of compact, long-lived stable sources of small amounts of power. Such cells will be immune to environment and particularly to low temperatures. It is very true these developments are in their experimental stage, but high voltage nuclear cells have been demonstrated with strontium batteries, and it is very possible that polonium 210 may become available for use as a heat source for the thermoelectric nuclear cell or battery and may become economical.

Representative VAN ZANDT. Are you familiar with the light the Pennsylvania Railroad has developed and installed in its switching operations in the Altoona Yard?

Mr. MCBRIAN. I should be because we were the first to start work with radioactive light sources.

Representative VAN ZANDT. Describe it, if you will.

Mr. MCBRIAN. It is a krypton 85 light cell. The ones we have had, have had a half life of 12 years. Economically we could order them now in hundreds on the railroad, but we have been stymied by the fact that the AEC has had this for a review as to whether it should be released for the public because it is the first application to be put out free. They have given us and the Pennsylvania and other railroads the freedom to use them as experimental units. We could use hundreds of them. If we could make hundreds of them, we could make it economical. Nobody has given us the green light.

Representative DURHAM. What is the hazard?

Mr. McBRIAN. It is no more a hazard than using neon tube lights with selenium which you have now.

Representative VAN ZANDT. How much experience do you have as far as this type of light is concerned?

Mr. McBRIAN. Only the experimental work. We have installed it in railroad yards, and have used it, and we know it is satisfactory. We can get perfect green color; perfect yellow color. Our red colors are not yet developed to the intensity that we want. We would not need to use the red to begin with because we have enough lights in the yards for sidetracks, and so forth, where yellow and green lights could be used if we could get them released. Economically we figure that even at a price of $400 or $500 or $600 a lamp, we would save at least $75 a year on their installation, based on the maintenance.

Representative VAN ZANDT. How many railroads are using the light?

Mr. McBRIAN. New York Central, Pennsylvania, we are, and the Association of American Railroads. Nobody is universally using them because we have not secured a release for the general application.

Representative VAN ZANDT. What does the lamp cost?

Mr. McBRIAN. The first lamps cost us between $300 and $400.

Representative VAN ZANDT. Apiece?

Mr. McBRIAN. Yes.

Representative VAN ZANDT. How does this cost compare with the conventional type lamp?

Mr. McBRIAN. The conventional type lamp costs about $75.

Representative VAN ZANDT. $75?

Mr. McBRIAN. You have 12 years half life and no maintenance. It soon pays itself out.

Representative VAN ZANDT. The conventional type lamp uses oil?

Mr. McBRIAN. We also have some electric powered lamps. We could use this atomic lamp in many places where we don't have electric power. Incidentally, the biggest inquiries that we have had for the use of this atomic lamp has been contractors in the United States. We have been flooded with letters because they want to use them where they have detour signs and such places. We have had tremendous inquiries on this.

Representative VAN ZANDT. From what you say this lamp is already economical.

Mr. McBRIAN. It is already economical and developed. We need to get it released.

Representative DURHAM. Do you extract your own krypton?

Mr. McBRIAN. No. We have had U.S. Radium or the Walter Kidde Laboratories or others who make these lamps do this work. They get the source krypton to make such lamps.

Representative DURHAM. They get it from where?

Mr. McBRIAN. I suppose they purchase that from the AEC at Oak Ridge.

Representative DURHAM. You could extract it if you have the ability to do it. I don't see why there is any restriction on krypton.

Mr. McBRIAN. This is radioactive krypton 85.

Representative DURHAM. That is different, of course. It is a very rare element.

(A letter received from the AEC, on the availability of krypton for civilian use, follows:)

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., February 24, 1959.

Hon. CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy,
Congress of the United States.

DEAR SENATOR ANDERSON: This is to inform the committee that the Atomic Energy Commission has increased the availability of krypton 85 from 20,000 curies to 100,000 curies annually for civilian industrial uses.

Krypton 85 is finding increasing use for activating phosphors in self-luminous light sources. Some of the major applications where its adaptability has been established and units designed and tested are in emergency aircraft markers, mine safety lamps, ship bulkhead and deck markers, darkroom safety markers, aircraft drogue, wing tip, and tail light illumination, and road sign markers. Krypton 85 is also routinely used in thickness gages on production lines to help produce more uniform paper, plastics, rubber, and numerous other materials.

Krypton 85 is produced by fission of uranium in a nuclear reactor. This by-product may then be obtained by extraction from reactor fuel element chemical processing plant off-gases.

Sincerely yours,

A. R. LUEDECKE,
General Manager.

Mr. MCBRIAN. Under the law, aren't we required for the use of any radioactive materials to have it released?

Representative DURHAM. That is true.

Representative VAN ZANDT. Will the witness tell us, what are the possibilities of contamination in the event of release of krypton gas?

Mr. MCBRIAN. As we understand it, suppose a boy would shoot a rifle bullet through it; unless he breathed it or swallowed the material, there is no danger. He would have to be absolutely in direct contact with it and ingest it into his system.

Representative VAN ZANDT. In other words, the possibility of contamination is insignificant.

Mr. MCBRAIN. For example, the selenium electric tube lights that we have are just as dangerous.

Representative DURHAM. Of course, it comes from the fission. It comes from the sun, too.

Mr. MCBRAIN. Yes. I would like to make another statement. We have also found in our studies that the liquid petroleum fuels can definitely be improved with very low dosages of irradiation. For example, when petroleum energy fuels are now studied with the electron microscope, they are found to be colloidal in nature, having definite particle size. The presence in the fuels of such deleterious elements as sulfur, vanadium, and so forth, are directly related to concentration in the larger sizes of these unstable constituents in these fuels. Such fuels then give resultant service troubles through corrosion, wear, and deposits in internal combustion engines. When these particle sizes exceed 1 to 2 microns, and even are found in as large a size as 50 to 60 microns, then operating problems arise with internal combustion engines.

Through irradiation these particle sizes have been reduced to the order of one-fourth to one-half micron, and with actual engine tests being run in the field, wear rates of high sulfur fuels have been reduced to that of low sulfur fuels and resultant corrosion and deposit problems eliminated. Unfortunately, the studies have been made with

various types of radiation and at various radiation facilities. The need for working out standards of such dosages under same conditions has been very apparent in the results which have been obtained. This again offers a possibility for utilization of waste materials to be put to practical use whereby industry could improve present energy fuels.

We have for the last 6 months been running standard diesel tests in order to investigate some of these effects.

Representative VAN ZANDT. Would the witness tell us does this radiation treatment of liquid petroleum decrease the air pollution or help to solve the smog problem?

Mr. MCBRIAN. We have had a lot of arguments about this. If the smog problem is one of irritation such as would come from sulfur or sulfur dioxide or aldehydes, no, but if the smog problem is the result of chemical reactions due to the fact that particles of unburned constitutuents of fuel react to cause the smogs, then yes, very definitely it would.

Representative VAN ZANDT. It is possible we have a partial answer to the smog problem.

Mr. MCBRIAN. As a possibility we should run tests to find out.

Representative HOLIFIELD. What you are saying is that you get a more complete burnup of the fuel, and therefore there is less unburned products thrown into the air.

Mr. MCBRIAN. Yes. My statement was that present fossil fuels, gasoline, diesel fuel, and so forth, are colloidal. There are lots of arguments about it, but it is true. We have been running our railroad on this principle. We have no specifications for fuel; we buy on particle size only. We prepare our fuels for that very purpose. The burnup is the answer. You get a cleaner burnup.

Representative DURHAM. You may proceed.

Mr. MCBRIAN. Another very important use which we have found for atomic energy has been the possible development of light sources to replace conventional lighting, signals, and signs with radioactive sources which will have a long half life. This will find good application in the railroad industry providing that releases can be secured for the application of these into the field without having to be subjected to long delays and a critical study as to whether such facilities are to be found more unsafe than some of the present types of conventional lights which are now used.

Representative VAN ZANDT. We are using krypton gas for a switch light.

Mr. MCBRIAN. Yes.

Representative VAN ZANDT. What about your automatic signals and so forth?

Mr. MCBRIAN. There we would not use this switch lamp. With the automatic signals we would have to have some kind of triggering device. There we hope to develop nuclear batteries to replace the present wet batteries which fail sometimes.

Representative VAN ZANDT. What about the application of radiation to the elimination of ice which interferes with the operation of switches?

Mr. MCBRIAN. We have not tried that. That is a very good suggestion. We have not tried that at all.

In closing I would like to make a few remarks concerning the declassification and dissemination of information on atomic energy.

A great amount of work has been done by the Atomic Energy Commission in releasing information. This information however has been primarily intended for people who are carrying out the specific AEC programs. Much less consideration is given to those whose interests and areas of applications are either outside of the knowledge or of the programs of the AEC. If more general freedom of communication is allowed, I am sure that the ideas created and the applications found will be of immense value to our country.

Representative DURHAM. Mr. McBrian, you have made a very able statement. I think you are the first man who has appeared before this committee, and I have been on it since its inception, to come up with a novel idea. I think the AEC should get in touch with you, instead of you getting in touch with the AEC, and get some information from you. This is one of the most amazing statements that has been made before this committee.

Mr. MCBRIAN. Thank you.

Representative DURHAM. What is your background?

Mr. MCBRIAN. I am a metallurgist.

Representative PRICE. About 4 years ago at 1 of these 202 hearings with the Commission before us, I asked questions about the feasibility of atomic proplusion for railroads. The reply I received at that time was that the railroads would not be interested in this because of the economics. They could do the job so much more reasonably from existing fuels so that there would be no interest in this program. What is your comment on that?

Mr. MCBRIAN. My comment is that I can't speak for the other railroads. Our railroad is interested in any type of energy development that is an improvement over what we have, and will save money and do a better job of performance for our railroad. Atomic energy has such a possibility, and therefore we are making a study as to its possibilities.

Representative VAN ZANDT. What type of coal is volatile coal?

Mr. MCBRIAN. One that has from 20 to 30 percent of these aromatic constituents, like methane and hydrogen. Anthracite, for example, is not a volatile coal. Some of the bituminous coals are very hard coals. The coal in Utah and Colorado and a lot of the coals in Virginia are volatile coals.

Representative VAN ZANDT. That is in southern Virginia.

Mr. MCBRIAN. Yes, and Kentucky. The higher the volatile content, the better the job we do with radiation. That is what we believe. The lower volatile ones, until we know may be higher dosages or longer periods of time of exposure might do something.

Representative PRICE. The experiments that you are doing with coal, if they were successful, would provide an increased market for coal?

Mr. MCBRIAN. Yes. For example, we are using all petroleum fuel on our railroad. For example, we have burned 10 percent coal in our little experimental engine. There is probably no reason why we could not go to 50 percent. That would mean that there would be a coal market on our railroad where there is no market now.

Representative VAN ZANDT. What effect would this have on the production of coke from coal?

Mr. McBRIAN. We don't know. That is one of the research problems we want to undertake to see, if you could not make a coking coal from coal by irradiation. We have a hunch maybe it could be done.

Representative VAN ZANDT. In other words, you would improve coke?

Mr. McBRIAN. I don't know. That is one of the problems that we have as a program that we would like to do for our coal people.

Representative VAN ZANDT. Thinking about the atomic locomotive for a moment, it has been said that a reactor the size of a trunk could produce the energy necessary to propel a locomotive around the earth at the Equator several times. Would you concur in this statement?

Mr. McBRIAN. I did not understand what the size was.

Representative VAN ZANDT. A reactor the size of a trunk would furnish the energy to propel a locomotive around the earth at the Equator several times.

Mr. McBRIAN. It all depends on the type of reactor that is developed. For example, the reactor studies that we have made in this joint study—and this has not been verified except theoretically—is that we would use a free piston type construction having a barrel in which will be comprised the reactor and engine, the piston moving back and forth. This would be conceivably of the order of 36 inches diameter and maybe 10 or 12 feet long. That would be all there would be outside of the shielding and cooling equipment. The amount of fuel would depend entirely on us. If we wanted to have a period between overhauls of 3 months, we would supply a storage of enough U^{235} plus whatever uranium we would use as a fuel and use that. If we wanted to make it larger, we would have to increase the amount of fuel. Conceivably, as I see it, you could put enough uranium to do what you say. I don't know what the size of it would be. Not with our reactor, you could not.

Representative VAN ZANDT. What about the shielding? I am thinking about a collision and rupture of the shielding. Do you think you can shield this hot material to the extent that in the event of a collision there would be no contamination of the area?

Mr. McBRIAN. We would say this. Unless we could meet all the existing requirements for safety, we would not ask for an atomic-powered locomotive to be used on the railroad. It is conceivable that this could be encased in solid cast iron and have a working fluid that is regenerated once in a while. Then we think there would be no danger of it. But we will not know until we make the research to see if it is feasible or possible.

Representative VAN ZANDT. Have you in mind any amount of money that you think the Atomic Energy Commission could make available for the purpose of assisting your effort, whether it be locomotive, irradiation of coal, liquid fuels, or something else?

Mr. McBRIAN. The only thing we have is this. We know to develop an experimental reactor as a prototype costs money. This reactor for a railroad unit could be used by the REA or the Army Transportation Corps or others. The money that would be required to develop such a reactor, in my opinion, would be more than one railroad such as ours could afford to expend. Since it could be of national scope, we would like to see somewhere a program developed for re-

actors of these small capacities which could be utilized in such a unit, be it railroad locomotive, REA development or Army Transportation Corps, or a package power unit.

Representative DURHAM. Thank you very much, Mr. McBrain. We appreciate your coming here.

Mr. MCBRIAN. Thank you.

(Correspondence between the Joint Committee and the AEC commenting on these radioactive isotope applications described by Mr. McBrian follows:)

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
February 26, 1959.

Mr. A. R. LUEDECKE,
General Manager, U.S. Atomic Energy Commission,
Washington, D.C.

DEAR MR. LUEDECKE: We would like to receive your comments on the radioactive isotope applications described by Mr. Ray McBrian of the Denver and Rio Grande Western Railroad Co. at the section 202 hearings on February 25, 1959. A copy of his statement is attached.

We would particularly appreciate your comments on the following points in Mr. McBrian's statement:

(*a*) Has the Commission reviewed the technical aspects of the work described by Mr. McBrian?

(*b*) If so, what is the Commission's technical evaluation of the work?

(*c*) Is similar work being performed by others on the upgrading of coal and liquid petroleum fuels and the development of light sources using radioactive isotopes? If so, what promise is indicated by the work?

(*d*) In what way is the Commission cooperating with the Denver and Rio Grande Western Railroad in the atomic research work described by Mr. McBrian?

(*e*) Has the Commission received requests for additional assistance from the Denver and Rio Grande Railroad in support of their work? If so, what action was taken by the Commission in response to the requests?

(*f*) Has the Commission received licensing requests from the Denver and Rio Grande or others for the use of radioactive light sources for railroad signals? What is the status of action on such requests?

Sincerely yours,

JAMES T. RAMEY, *Executive Director.*

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., March 12, 1959.

Mr. JAMES T. RAMEY,
Executive Director,
Joint Committee on Atomic Energy,
Congress of the United States.

DEAR MR. RAMEY: Following is the information requested in your February 26, 1959, letter concerning radioisotope applications described by Mr. Ray McBrian of the Denver & Rio Grande Western Railroad Co. The statements correspond alphabetically with the questions presented.

(*a*) Information heretofore available to the Commission concerning Mr. McBrian's work is essentially the same as that he presented at the section 202 hearings. A contractor conducting a study for the Commission of industrial radiation applications visited the Denver & Rio Grande laboratories to obtain information about this work. Mr. McBrian also visited the Commission for further discussion of his program. These discussions did not extend to detailed technical review of Mr. McBrian's work.

(*b*) The Commission was impressed with the potential industrial significance of Mr. McBrian's studies should they prove feasible on a commercial scale. Not having access to the experimental data, however, we have not been in a position to make a technical evaluation.

(*c*) We are aware of a few groups having conducted studies on coal somewhat similar to Mr. McBrian's. There likely are others of whom we do not have direct knowledge. The ones we know about include the Bureau of Mines, University of Michigan, Pittsburgh Consolidation Coal Corp., and Armour Research Foundation. So far as we are aware, the work is in very early research stages.

With regard to light sources using radioisotopes, several commercial concerns have developed and are marketing these devices. Tritium and krypton 85 are the principal isotopes used. New England Nuclear Corp., and U.S. Radium Co. are the major manufacturers. As you may know, on February 26, 1959, the Commission announced availability of 100,000 curies per year of krypton 85 for industrial purposes such as this.

(*d*) In conducting his program, Mr. McBrian has utilized the facilities of AEC National Laboratories for irradiating coal. Additionally, last October the Commission invited Mr. McBrian to discuss his program with the Commission staff at his convenience. He met with our Office of Isotopes Development on January 29, 1959. At this meeting, Mr. McBrian was invited to submit a contract proposal for consideration under our isotopes development program setting forth the nature and extent of Commission assistance he might desire. We have not yet received such a proposal.

(*e*) Except in connection with the foregoing discussion, no requests for assistance have been received from Denver & Rio Grande Railroad.

(*f*) Licenses have been issued to three railroads for trial installations of krypton 85, signal lanterns. The Denver & Rio Grande Western Railroad Co. has been licensed since December 13, 1956; New York Central System since April 8, 1957; and the Pennsylvania Railroad since January 15, 1958.

Only one application is currently pending. This is an application dated January 26, 1959, by the New York Central System for an amendment to their license to use these devices throughout their system. Because of the level of gamma radiation from the lanterns it is necessary that they be installed under controlled conditions and secured against unauthorized removal. Several questions of systemwide control and accountability need to be resolved and additional information bearing upon these questions has been requested of the company. Action on the pending application can be taken promptly when the information has been received.

Sincerely yours,

A. R. LUEDECKE, *General Manager.*

Representative DURHAM. The committee is adjourned until 2 o'clock tomorrow.

(Thereupon at 5:25 p.m., Wednesday, February 25, 1959, the committee adjourned until Thursday, February 26, 1959, at 2 p.m.)

DEVELOPMENT, GROWTH, AND STATE OF THE ATOMIC ENERGY INDUSTRY

THURSDAY, FEBRUARY 26, 1959

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C.

The committee met, pursuant to recess, at 2 p.m., in room P–63, the Capitol, Senator Clinton Anderson presiding.

Present: Senators Anderson (chairman), Jackson, Hickenlooper, Dworshak, and Bennett; Representatives Durham, Holifield, Price, Van Zandt, Aspinall, Hosmer, Bates, and Westland.

Also present: James T. Ramey, executive director; John T. Conway, assistant staff director; David R. Toll, staff counsel; George F. Murphy, Jr., professional staff member; Edward Bauser, technical adviser, Joint Committee on Atomic Energy.

Representative HOLIFIELD (presiding). The committee will come to order.

Our first witness today is Mr. Francis K. McCune, of the General Electric Co.

Mr. McCune, we will be glad to have you come forward to the witness table.

TESTIMONY OF FRANCIS K. McCUNE, VICE PRESIDENT, GENERAL ELECTRIC CO., ACCOMPANIED BY WILLIAM F. KENNEDY, COUNSEL FOR THE ATOMIC PRODUCTS DIVISION, GENERAL ELECTRIC CO.

Mr. MCCUNE. Mr. Chairman and gentlemen, I have a statement. My name is Frank McCune. I am testifying for the General Electric Co.

Representative HOLIFIELD. You may proceed with your statement.

Mr. MCCUNE. It is a pleasure to appear before you once again in your annual 202 hearings. I plan to comment briefly on six of the topics mentioned in your invitation to testify: The domestic power program, the Euratom program, nuclear maritime propulsion, declassification, Commission contract policy, and organization and administrative problems.

THE DOMESTIC POWER PROGRAM

In my letter of October 31, 1958, I commented in detail on the staff paper put out by the Joint Committee last August. I believe that the opinions I expressed at that time are still valid today. In gen-

eral, I am in agreement with the objectives outlined in the staff paper and differ only as to some of the methods.

Since that time the Commission has published the report of its ad hoc committee. Again I find myself in agreement with much of the report—and particularly with its emphasis on the necessity for continuing critical examination of each reactor type and for concentration on types with good long-range potential.

The developments since last summer all indicate widespread agreement on the essential objectives—the differences as to objectives are largely in formulation and in precise timing. Inevitably there are some disagreements as to the best way to attain these objectives.

Here there are many conflicting considerations and it is understandable that reasonable men will differ. Nevertheless, I believe that the continuing discussion has been fruitful in clarifying the issues and narrowing the areas of disagreement.

One of the basic premises of my October 31 letter is that industry can make a major contribution in the selection and development of economic reactor types. Indeed, it is fair to say that the economics of a reactor type cannot be proven without industrial participation on a risk basis.

General Electric has invested a great deal of money in studying known types of reactors and what must be done to improve them. I believe, as you know, that the boiling water design has the best prospect of meeting your objectives at the earliest date with the least expenditure of money. Accordingly, I hope that the boiling water design will be one of the types on which the national effort will be concentrated in the next few years.

The General Electric Co. has developed a systematic program for exploration of the boiling water concept; this development program has been broken down into a series of carefully defined and interrelated tasks. While certain tasks are of the type which have been and we hope will continue to be part of the Atomic Energy Commission's continuing research and development program, the principal requirement is the building and operating of a number of carefully chosen prototypes and, I might add, different prototypes. I am hopeful that enough members of the power industry will be interested in this latter program to bring it to a successful conclusion.

Any decisions as to help needed or not needed from the Government for plant construction must come from members of the power industry individually. I do not believe it is realistic to assume that help given to the equipment manufacturer, who actually produces only a small portion of the plant in his factories, can solve the problem.

If Government help is to be provided then I believe that the suggestion made in Chairman Anderson's statement of January 30, in the staff paper, and in the Commission's proposed authorization bill, namely, Government contribution to plant cost, represents the most desirable form of aid. Any such contribution should be made on a basis which is equitable to all interested groups and on a basis which preserves some risk for the private participants in the project.

For its part, the Commission must continue to be responsible for the basic program of research and development. It is obvious that this program will have to be revised from time to time in the light of

technical and other developments. I endorse the suggestion of the ad hoc committee that similar committees should be appointed from time to time to review the program. Also, I believe that in its research and development work the Commission could make greater use of private industrial laboratories and thus broaden the base of industrial competence and participation in the atomic program.

EURATOM PROGRAM

As you know, the program of cooperation with Euratom has my endorsement. I would like to emphasize briefly three points I have made on prior occasions:

First, a solution of the liability program by the interested European governments is essential to the success of the program. Also, I believe that such a solution is increasingly urgent. Work is going forward on European projects under direct contract with the customer, and will also be going forward under research and development contracts with the Commission.

In this connection I think that for European projects, U.S. suppliers should be afforded protection equivalent to that afforded foreign suppliers under the Price-Anderson Act. This does not mean that European governments should necessarily copy the Price-Anderson Act, but only that as far as suppliers' liability is concerned, the net result should be the same.

Also, I believe that U.S. Government legislation should be enacted protecting American suppliers against suits in U.S. courts based on foreign incidents.

Second, I do not believe it wise for the U.S. Government to involve itself in the selection of reactor types for different countries; I hope that the administrative arrangements for project review will avoid any such involvment.

Third, the documents on the fuel cycle guaranty arrangements which I have seen thus far contain provisions of great complexity. If we are to avoid serious difficulties and complications in this area, we must have a simplification of these arrangements.

NUCLEAR MARITIME PROPULSION

For the past 2 years General Electric has been studying the application of boiling-water reactors for maritime ship propulsion. Last year we completed for the Commission a preliminary design study of a reactor system for the conversion of an existing tanker hull to nuclear propulsion. Recently we agreed to undertake for the Commission a further design study for a complete nuclear propulsion system for a large tanker.

Our studies show that maritime applications are ready for serious development. This is not true yet in the great bulk of short-run, passenger and small freight vessels. It is uniquely true in the case of large, long-run tankers. While even these are not yet fully competitive, the astounding fact, and it is astounding to me, is that it now appears such applications may actually be closer to present economy than is any land-based electric power concept. The present rate of learning and reduction to practice in boiling-water reactors should

lead to further reductions in plant costs and to improvements in performance. We believe that the Maritime Commission is working effectively with the Atomic Energy Commission to this end.

If additional U.S. nuclear merchant ships, either privately owned or Government-owned, are to be constructed, liability protection legislation will be required. Also, I am pleased to note that the Commission and the Maritime Administration have been invited to assist in a revision of the international maritime liability conventions to deal with the nuclear problem.

DECLASSIFICATION

The progress to date in declassification has substantially eliminated the problems in the domestic reactor field; however, we feel there is a continuing need for periodic review of the declassification system to take into account those problems which remain which are inextricably involved with national defense. For example, production-type reactors can be designed to produce great amounts of electric power, but the power industry in general is excluded from evaluating or contributing to the effectiveness of this approach due to the classification which surrounds the production of plutonium.

Again, the actual costs of raw and enriched fuel, plutonium, material reprocessing, heavy water, and some of the plants which produce them, are still classified. Hence both domestic concerns and foreign nations are precluded from making realistic appraisals of many reactor systems for future potential. It is our opinion that the prices established by the Commission for U^{235}, plutonium buy-back, heavy water, chemical reprocessing, and the like are the result of a sincere attempt on their part to be realistic, but the tremendous Government weapons material demand undoubtedly is responsible for substantially higher costs of natural uranium and U^{235} than would otherwise be the case.

I believe that much international concern over natural uranium reactors would be eliminated if it were possible to declassify diffusion costs, even though the processes might still be classified.

If this whole area cannot be declassified, possibly a team of cleared accountants and men with business knowledge of the processes involved should examine the entire subject carefully, making public their assumptions, conclusions, and as much supporting data as is possible within the limits of security.

COMMISSION CONTRACT POLICY

The contract policy of the Atomic Energy Commission has been generally criticized as based on a lesser understanding of industry and industrial practices than is the case of older Government agencies. I am pleased to note in Mr. McCune's testimony that the Commission is giving continuing attention to this subject.

Many contractors are looking forward to completion of a study, sponsored by the Atomic Industrial Forum, addressed to the financial aspects of the Commission's contract policy. This study is being made by the dean of the Business School of the University of Illinois, a former Controller of the Commission. When this is complete, I

believe all of us will be more confident in expressing our views and that we will have a fruitful basis for discussion.

I should like to emphasize the importance, in this area especially, of continuing consultation between the Commission and industry. I hope that the Commission's reexamination of its contract policy will be a continuous process and that in the course of this reexamination it will freely solicit and fully consider the views of its contractors.

ORGANIZATION AND ADMINISTRATIVE PROBLEMS

Specifically, I have no criticism of the organization of the Atomic Energy Commission. Those divisions having to do with the civilian power program are, in my opinion, working hard and earnestly to do their job. However, most actions of a regulatory nature are now on a permissive licensing basis. In essence, the prospective licensee prepares extremely detailed data and presents it specifically to the Commission. The Commission staff must study it in detail, and usually after much additional clarification, depending on how accurately the originator guessed as to what the staff would feel they needed to know, the Commission then approves or disapproves that specification or proposed action.

I do not believe that an industry can be built in any reasonable period of time under such an approach. We must convert to a system of written regulations, with the private owner assuming the risk for violation, before any substantial number of commercial establishments can reasonably operate.

The Commission recognizes this problem and is trying to cover many fields on a broad basis. Nevertheless, the degree to which this is accomplished may well in the end determine whether, after we technically achieve economic power, it is actually put to work. Unless the codification of the licensing system and its reduction to a set of written rules and regulations keeps pace with accelerated engineering development, the results will be very disappointing.

I wish to express my appreciation for the opportunity to appear before you today. I have attached to this statement several exhibits which will bring the record up to date on some of the General Electric Co.'s activities in the power reactor field.

(The supplement referred to follows:)

[EDITOR'S NOTE.—Exhibit narrative descriptions are printed below, photographs included in exhibits are on file in the offices of the Joint Committee.]

EXHIBIT 1

The Dresden atomic power station which the General Electric Co. is building for the Commonwealth Edison Co. and the Nuclear Power Group is 66 percent complete.

The project is approximately 6 months ahead of schedule and so far the costs are running within our 1955 estimates.

EXHIBIT 2

The General Electric 30-MW materials testing reactor at the company's Vallecitos Atomic Laboratory has been completed and full power license "TR No. 1" was received on January 5, 1959.

EXHIBIT 3

The Vallecitos boiling water reactor has performed according to expectations. The plant was shut down for a short period in late 1958 after 1 year of operation for system inspection. At that time, the general radiation level around the dis-

assembled turbine was less than 1 mr per hour. This means that a man working on the turbine for 1 work-year would receive less than one-half of the permissible yearly dosage.

The plant at the time of shutdown had operated for 5,600 hours, generating 93 million thermal kilowatt-hours and 16,733,000 kilowatt-hours of electric power.

EXHIBIT 4

Artist's conception of the Pacific Gas & Electric Humboldt Bay 50 MW nuclear powerplant for which the General Electric Co. will design and build the reactor.

EXHIBIT 5

The General Electric Co. has been designated to construct a 150 MW boiling water reactor for the Societa Elettro-Nucleare Nazionale in Italy. Engineering work is now underway on this project. (Artist's conception above.)

The AEG RWE 15 MW boiling water reactor which the General Electric Co. is building for Germany is proceeding on schedule and is expected to be completed by 1961.

The General Electric Co. is continuing negotiations for the suisatom 15 MW boiling water reactor powerplant in Switzerland.

NOTE.—The operating dates for all foreign projects are contingent upon the successful solution of the foreign insurance and liability problem.

Mr. MCCUNE. I have simply given you some pictures of some of the outstanding projects to show you where they are. We are particularly proud of the first industrially owned material testing reactor, which is now operating. We are very happy with more than a year's performance of the Vallecitos reactor.

I will point out one little thing on that statement: I think we have dispelled the fear of radioactive contamination of the system out of a boiling water reactor.

I will point out the note on the European projects. As far as I know, those and all other European projects have their dates of completion contingent on the solution of the liability problem. I do not know of any group who wants to complete a station until that problem is solved.

That, sir, is my testimony.

Representative DURHAM. Thank you very much, Mr. McCune. In your statements you always bring thoughts of benefit to the committee, in arriving at conclusions on procedures and what we have to do.

I notice what seems to be one of your main complaints here is the fact that you do not have enough knowledge on the cost of the production of plutonium and uranium 235. What did you ask the Commission on that? How should we arrive at a decision as to the cost?

Mr. MCCUNE. Let me explain, if I may. I believe I should explain it a little more, based on your question, if you will allow me. I have pretty good knowledge of the cost of production of plutonium.

Representative DURHAM. That is what I thought.

Mr. MCCUNE. I was not complaining for myself. In fact, I was not complaining. I was saying that I do not think industry generally, nor the foreign countries we are trying to help, are in any position to make their own determination, nor are other businesses in the United States, if they didn't have equal information to mine on the production cost of plutonium, and that isn't right.

I believe more information as to the actual cost of producing uranium 235 would be extremely helpful. We have made studies, for example, based on incomplete information, which would show it would be far cheaper for Europe, assuming they could build a diffusion plant,

knew how to build a diffusion plant, and produce enriched reactors, than it ever would be for them to base an electric industry based on natural uranium reactors.

They are in no positon to guess this. This is where the classification for defense enters.

Representative DURHAM. I took your statement to mean industry altogether, and not just a few individuals. Of course, I can understand why the main product, plutonium and uranium 235, is supposed to be bought back and will be bought back by the Government under the law at the present time.

That can become a very important part as to the overall project cost. You do not feel that industry as a whole has information enough to base factual knowledge in going in and building a reactor. This, of course, will be part of the operating expense or the buy-back, whatever you want to call it, by the Government.

Mr. MCCUNE. That is correct.

Representative DURHAM. Do you feel that under the present conditions, being classified as it is, that we would run any risk of making this information fully available to countries like Euratom, which we are supposed to be cooperating with?

I assume you are applying the statement to them as well as to industry in this country.

Mr. MCCUNE. I have great difficulty with that specific question for this reason: We tell broadly how many warships we have, how many airplanes we have; every time we fire a missile it is pretty well known, and yet we keep totally classified our quantities of atomic material. This is a judgment decision.

It may be right or it may not be. It is one that you and the Commission have to wrestle with under the present law. If the quantity were not classified, then it seems to me it would be possible to release a great deal of background data which would enable many businesses and other nations to make much more sensible decisions than they can make based on an arbitrary price schedule.

If that is impossible, and maybe it is, in your judgment, then my suggestion was that it might well be possible for a team of expert people to establish cost figures, hypothetical cost figures, as, for example, what uranium 235 would cost with different world demands and with a plant built specifically just to produce the kind of uranium 235 you need for low-enriched reactors.

This, again, might allow people to make better economic decisions. I happen to be one of those who, based on my imperfect knowledge, believe that there is little reason to consider any kind of reactor which is not an enriched reactor.

You will find plenty of poeple who disagree with me, and I believe that the disagreement wholly centers on lack of information in this area.

Representative DURHAM. Of course, I have never seen the point in the complete secrecy, you might say, of the cost of the production of these materials.

Now, as to the amount, that is a different question entirely. But I do not understand how this would be divulging too much information which would be of value to our enemies.

Mr. McCUNE. Without getting on the other side of the fence, I believe the assumptions are that if the actual production costs were known and the appropriations for production were known, by division you would come up with quantity and it would not be very inaccurate. I do not know whether that is true or not.

Representative DURHAM. Well, I do not put much credence in that. You can always deduct and make decisions on the basis of appropriations, but that does not give too much information.

Are there any questions?

Representative HOLIFIELD. I think your suggestion at the top of page 7 is a very valuable suggestion, Mr. McCune. I would assume if such a program would be valuable to industry, there would be no reason why it could not be followed from a security standpoint providing they would come up with conclusions or assumptions which would be based on the reasonableness of the price range which had been established, rather than going into a breakdown as to the way in which the information was considered in order to come to that conclusion.

It seems to me it is a very reasonable and solid recommendation.

(Additional information on this subject is contained in the following exchange of correspondence between the Joint Committee and the AEC.)

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C., February 27, 1959.

Mr. A. R. LUEDECKE,
General Manager, Atomic Energy Commission,
Washington, D.C.

DEAR MR. LUEDECKE: Enclosed is a copy of a statement presented before the Joint Committee on February 26 in the section 202 hearings by Mr. Francis K. McCune, vice president, General Electric Co.

Congressman Holifield would appreciate receiving the Commission's comments concerning sections of Mr. McCune's statement set forth on pages 6 and 7 under the heading of "Declassification" and, in particular, to the following sections:

Page 6, first paragraph: "For example, production-type reactors can be designed to produce great amounts of electric power, but the power industry in general is excluded from evaluating or contributing to the effectiveness of this approach due to the classification which surrounds the production of plutonium."

Page 6, third paragraph: "I believe that much international concern over natural uranium reactors would be eliminated if it were possible to declassify diffusion costs, even though the processes might still be classified."

Page 7, first paragraph: "If this whole area cannot be declassified, possibly a team of cleared accountants and men with business knowledge of the processes involved should examine the entire subject carefully, making public their assumptions, conclusions, and as much supporting data as is possible within the limits of security."

Thank you for your assistance in this matter.

Sincerely yours,

JAMES T. RAMEY, *Executive Director.*

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., March 25, 1959.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States.

DEAR MR. RAMEY: This is in reply to your letter of February 27, 1959, transmitting Mr. McCune's statement before the Joint Committee on Atomic Energy on February 26 and requesting the Commission's comments on his remarks concerning declassification.

I am pleased that Mr. McCune noted the substantial progress made in the field of declassification and wish to again assure the Joint Committee that the AEC fully recognizes the "continuing need for periodic review of the declassification system to take into account those problems which remain which are inextricably involved with national defense," and that we will continue to modify our classification rules as often as circumstances warrant.

We have recognized that production reactors can be designed to produce great amounts of electrical power. Our current production reactors are, of course, not of this type. Since present units are engaged wholly in the production of military material, they have been held classified primarily in order to protect the production rates and stockpiles of plutonium. However, it is not correct to say that the power industry has been excluded from evaluating or contributing to the effectiveness of the power program "due to the classification which surrounds the production of plutonium." Much of the information concerning the production of plutonium has already been declassified. The technical classified information remaining in this field not related to actual production rates is being made available to industry through the access permit program. Through both of these means (declassification and the access permit program), therefore, industry can and has been looking at production reactor technology.

Mr. McCune also mentioned in the section on declassification his desire to see declassification of actual costs of raw materials, as well as of enriched fuel, plutonium, material processing, heavy water, and some of the plants which produce them.

The actual costs of raw materials for the United States and Canada have been declassified and published by the AEC. It is only because of agreements with foreign countries that some foreign procurement costs remained classified. However, the average cost of overseas uranium is also reported on an unclassified basis.

The matter of the cost of enriched fuel and the related matter which concerns diffusion costs again deal with a subject which has been a matter of continuing review by the Commission. As you know, production rates of U^{235} have been held classified as a matter which is considered to affect the national security. This, of course, requires that production costs, that is, diffusion costs, and the unit cost of enriched fuel remain classified since they could be used in connection with unclassified information to estimate production rates with reasonable accuracy. However, the availability of the published price scale for enriched U^{235} was intended to assist, on an unclassified basis, commercial interests in making necessary evaluations on reactor types.

The costs of materials reprocessing are classified only insofar as classified AEC unit costs are involved. However, certain of these classified costs again are and have been available to industry through the access permit program in any case where a need exists.

All of the costs connected with the production of heavy water are unclassified, and only those costs connected with the H_2S dual temperature process which reveal information concerning the process cannot be released because of a court injunction.

The plants which produce the materials which Mr. McCune has mentioned are classified only insofar as they might reveal the classified information discussed above. Thus, plants for the production of raw materials are unclassified. Plants for the production of plutonium are classified because to declassify them would reveal the rate at which plutonium is produced. Plants for the reprocessing of reactor fuels are unclassified except for those processing production reactor fuels (which remain classified for the reason just given) or when processing classified military reactor fuels. Plants for the production of heavy water are completely unclassified, although certain of the information cannot be made available at present, nor can access be granted due to the court injunction previously mentioned. AEC classification policy, however, is not in any way involved. Plants for the production of enriched uranium remain classified because the process by which the material is produced is classified.

With respect to Mr. McCune's suggestion to have a team of cleared accountants and men with business knowledge of the process involved, examine the subject carefully, we consider:

(*a*) that the Commission has declassified all of the information that it can without undue risk to the common defense and security;

(*b*) that the Commission is continuously reviewing all of its information with the purpose of declassifying additional information as soon as such an action can safely be taken;

(c) that the data which remain classified are being made available to industry through the access permit program wherever a legitimate need exists; and

(d) that the AEC price scales provide a useful unclassified basis for reactor studies.

We believe, therefore, that Mr. McCune's suggestion with respect to the "team of cleared accountants" would not contribute to the solution of the problem to which he refers.

Sincerely yours,

A. R. LUEDECKE, *General Manager.*

I want to comment a little bit on this liability problem that you bring out on page 4. I recognize, along with you, the importance of the solution of that problem, if we are going to have an export business. But I think this is a field where, from a practical standpoint, I do not believe that Congress would assume the task or the liability which would be involved in following manufactured articles all over the globe, articles such as reactors, or items such as reactors which might, through faulty operation, bring about liability damage, rather than any fault on the part of a defect in manufacturing.

It seems to me that if these places are anxious to get on with the job of developing the atom, that they are going to have to assume within reason the liability on the operation of these vehicles just the same as we are taking care of it here in the United States by our laws.

I think the governments there will have to assume that liability if they want to get on with the job.

Mr. MCCUNE. I am totally in agreement on that.

Representative HOLIFIELD. I am just thinking from a practical standpoint we could not follow these reactors to their eventual use and position.

Mr. MCCUNE. I do not think it would be right to ask our Congress to protect the citizens of other countries in this particular thing. I think that is the job of other countries.

The only thing I believe might be done is to say more or less a quid pro quo for the help is that they give the same general kind of protection which our Congress has extended here, and that if our terms, let us say, turn out to be far more liberal, and this is in essence for the protection of the public, then their terms, then they could not come over and sue in our courts to get the benefit of our terms against the manufacturer. This is a complicated legal problem, but it is a real problem.

Representative HOLIFIELD. Is it your understanding now that if a European manufacturer should sell a reactor in the United States that the present liability legislation of the United States would cover that? That is, cover it in case of an accident?

Mr. MCCUNE. As far as I am concerned, the present combination of insurance and legislation is entirely adequate for reactors produced by anyone and used within the United States. It does not cover reactors produced by people in the United States and used elsewhere.

Representative HOLIFIELD. That is right. That was part of my question. A reactor built by, let us say, an English concern that is sold in the United States—would that be covered by our liability insurance?

Mr. MCCUNE. Entirely.

Representative HOLIFIELD. On the other hand, if one of our manufacturers built a reactor and sold it to a firm in England, France, or

any other nation, there is no offsetting protection given to our manufacturer?

Mr. McCUNE. Not yet.

Representative HOLIFIELD. And which, of course, puts it, as you note, in a very unfair position as far as our own trade is concerned.

Mr. McCUNE. It is undeveloped. They are working on it.

Representative HOLIFIELD. I know there are committees meeting on it, and conferences. Of course, we will have to look at any of these machines sent overseas under the Euratom program. This has to be solved before they are exported, as you point out.

I want to comment on your exhibit No. 1, some of the information you give. You say it is 66 percent complete, that it is ahead of schedule, and the costs are running within the 1955 estimates.

I recognize there have been no public revealments of your cost figures on this by your company, but through the grapevine we got information that at some of your stockholders' meetings there has been some criticism of the cost of this particular reactor, and some indication that the formula for accounting that you are using spreads the cost over a number of potential succeeding reactors; and that the ultimate cost of this development is not apportioned to this one reactor.

I do not care whether you would care to comment on that, but we have read in the press these statements, and certainly your competitors are saying it.

Mr. McCUNE. I have been present at every shareholders' meeting of the General Electric Co. since this project was undertaken, and I do not recall any criticism. I have been pressed very strongly by the press to talk about the cost of this specific reactor.

The most effective way I have been able to cover this is to ask, for example, if this is X magazine, what they call the cost of the first copy of a magazine they ever printed. If they will tell me that, I might tell them when I finish Dresden what Dresden costs. But the physical estimates we have made, the estimates we have made for so much construction work, so much for the hardware, so much for these other things, are all coming within what we estimated back in 1955.

Representative HOLIFIELD. If you were presented today with a customer who would buy this same plant from you at the same price, would you accept it at that price?

Mr. McCUNE. No. Nor would we build a duplicate of Dresden today. We just have won an international competition on a similar plant, although an improved plant, in Italy, on which we quoted a price.

Representative HOLIFIELD. Similar in output?

Mr. McCUNE. It is 150 MWe instead of 180 MWe. It is improved. That price is there for the world to see.

Representative HOLIFIELD. Did you bid on that at prices reasonable to this?

Mr. McCUNE. We have bid on that at prices made to produce reasonable business.

Representative HOLIFIELD. Has that award been made yet?

Mr. McCUNE. Yes.

Representative HOLIFIELD. Did you folks receive it?

Mr. McCUNE. Yes.

Representative HOLIFIELD. Those are all the questions I have.

Representative DURHAM. Mr. Hosmer?

Representative HOSMER. I would like to pursue this international liability problem a little further.

Is the protection afforded to foreign suppliers under the Price-Anderson Act the same protection as afforded to domestic suppliers in the United States?

Mr. KENNEDY. The answer to that is "Yes," Mr. Hosmer, it is. There is no discrimination under the Price-Anderson Act between U.S. suppliers and foreign suppliers.

Representative HOSMER. The British, I believe, have dealt somewhat with this problem on an extremely more limited basis than we have. Is that right?

Mr. McCUNE. I think I can speak a little to that.

The British system has been, from what I have read of the British system—and some of this in the publications of the British Atomic Energy Authority—are that they consider that the act which established the Atomic Energy Authority gave them complete responsibility from a liability point of view for everything that was done in atomic energy.

When they produce an electric station, they are actually producing a station which is used by another arm of the British Government which is the British Electricity Authority. Under those circumstances, as I understand it, the British then believe that should an accident of any kind occur, the direct responsibility of the Atomic Energy Authority is there to cover whatever may happen.

But this all, of course, falls to pieces in anything that they might be doing in the way of export, and it certainly leaves them with the problem as they have mentioned many times in Parliament, that this does not help them a bit with the maritime situation or their naval situation, or anything of that kind. That is still under study in Britain.

Representative HOSMER. I take it your recommendation is not that the U.S. Government assume on up in excess of what insurance coverage you can get, but the liabilities should be limited to that point and then the foreign government would take over?

Mr. McCUNE. Maybe I can get a little more precise.

It is very likely that legislation may be passed. In fact, I believe it has been passed in Switzerland.

Am I right?

Mr. KENNEDY. Not yet. It has been proposed.

Mr. McCUNE. It has been proposed in many countries that liabilities might be limited at $7 million or $15 million, let us say, or something of the kind. Let us assume that there was an accident, and let us assume that the accident was even due to maloperation.

But let us assume that a jury might say, "Well, the manufacturer should have designed the thing so that it was impossible to operate it poorly." Therefore, the manufacturer would be responsible.

Representative HOSMER. Well, they would probably think that Americans are rich anyway.

Mr. McCUNE. That is it.

Well, I think that whatever the law of that country is it should apply. It would seem unreasonable to me that if the law of that country were far less favorable than our law, that a resident of that country or someone insured in that country could come in to our courts and sue us in our courts.

This may sound peculiar, but as I understand it, if, by international convention, for example, an individual were engaged in a tort and received a judgment against him, this could be in a foreign country, or the foreign individual could come to our country and sue if he thought he might collect more here.

And if a judgment was obtained, it could not only apply to the assets in the foreign country where it occurred, but any assets that the individual might have in many other countries who recognize this by treaty.

If we are not to have identical legislation on liability in all countries, it would only seem fair that they should not come over here and sue American manufacturers.

Is my point clear?

Representative HOSMER. Yes, I believe it is. It does not cover the situation of some of Switzerland's neighbors who might want to sue, too.

Mr. MCCUNE. This is another complicating problem.

Representative HOSMER. And anything less than a general convention on the matter amongst all the States not only that operate reactors but which are adjoining would be inadequate.

Mr. MCCUNE. That is right.

Representative HOSMER. At least for the purposes of standardization, that is. I believe that the only way we could possibly standardize would be to put certain limits on the jurisdiction of our courts to entertain the original suits or the establishment of foreign judgments. Is that what you had in mind when you said you believed that legislation should be enacted?

Mr. MCCUNE. Yes.

Mr. KENNEDY. That is essentially it; yes, sir. Generally speaking, our courts will apply foreign law to a foreign incident, but you cannot be completely confident because the conflict of rules are not that clear or precise.

Our suggestion is that we button this up by legislation which defines the jurisdiction of American courts for foreign incidents.

Representative HOSMER. Do you have any specific recommendations in that regard?

Mr. KENNEDY. Well, I think this, sir, that we certainly would want to consider giving effect in U.S. courts to any exclusive jurisdiction provisions, for example, in foreign treaties, and giving effect in American courts to the limits of liability in foreign treaties.

I think the precise form of the legislation depends to some extent on what the Europeans do by way of the OEEC convention, or some other arrangements for liability protection. But the principle is quite clear that it would be desirable by legislation to make it clear that American courts would give complete effect to the exclusive jurisdiction and ceiling provisions of foreign liability legislation.

Representative HOSMER. I think you mentioned before you delivered one reactor you have to have some kind of agreement from OEEC.

Mr. KENNEDY. Yes, sir.

Representative HOSMER. And whatever kind of agreement OEEC comes up with would have some effect on the terms of the legislation we might apply to our own courts; is that correct?

Mr. KENNEDY. The legislation in this country would have to depend to some extent on the form of solution that was adopted in Europe; yes, sir.

Representative HOSMER. Do you think it might be well in order to trigger some action, not only in OEEC but elsewhere, for the United States to start out, as of now, very strictly limiting the jurisdiction of the courts with the understanding that it might be adjusted upward to coincide with whatever general international agreements were arrived at?

Mr. KENNEDY. That is certainly a course I think the committee should consider; yes, sir. Hopefully, the Europeans will act very fast.

Mr. MCCUNE. I think it would be a good thing to have that ready, if I may say that. I think it would be very helpful if the committee had such a plan ready.

Representative HOSMER. I wanted to explore that.

You mentioned another difficulty, Mr. McCune, on page 4, these fuel cycles guarantees. Are you referring to that report, on what was made up as a supplement or an appendix; to the Euratom paper? Is that what you are talking about?

Mr. MCCUNE. Without being more precise, I think so; yes.

Representative HOSMER. These people that were negotiating this Euratom agreement, they sent some people off in rooms at various times to try to work out some fuel guarantee formula.

Mr. MCCUNE. Let me say the basic problem is this: It is easy to say that the U.S. Government will guarantee a fuel life of 10,000 megawatt days per ton, let us say. Now, what does this mean?

Representative HOSMER. That is what I am getting at.

Mr. MCCUNE. The moment you get down to what that means, you are in this situation, that the fuel in a reactor, for example, in various portions of the core, has entirely different degrees of irradiation, so how do you find out?

Then you have the problem if the Government is to guarantee something of this kind, does this mean, then, that in order to protect their guarantee they have to specify how the fuel is made, and if they specify how the fuel is made, will they have to enter your factory and exercise control over all the processes?

Does this mean, then, that having given some kind of guarantee, then our Government must take complete responsibility for the manufacturing process? What seems like a very simple little agreement becomes a very difficult thing to actually work out.

The second philosophy was that if industry will guarantee this, then the Government is required to do nothing. So far in reactors, and this would vary with different reactors, but so far we have been willing to warranty 10,000 megawatt-days per ton.

This seems very easy. Nevertheless, when you come down to writing up what we think such a warranty involves and how you go about measuring it, we might then be quite different from a Government formula.

I am just saying clarification of this, I think, is of extreme importance.

Representative HOSMER. Do you have any ideas as to how that might be done?

Mr. MCCUNE. Not at the moment. It is a complicated problem.

Representative HOSMER. I suppose you are discussing it with the AEC people?

Mr. MCCUNE. Industry groups have been talking with the Atomic Energy Commission on this problem.

Representative HOSMER. Mr. McCune, I know you are very familiar with the operations in a number of countries around the world. With that knowledge, do you believe that the United States is maintaining a world leadership in the nuclear field despite the larger number of kilowatts involved in the United Kingdom's program?

Mr. MCCUNE. Yes, I do.

Representative HOSMER. Would you like to say what you base that answer on?

Mr. MCCUNE. What I do believe is this, that in international competition for reactor sales abroad, American firms have done well, and I think this is the proof of the pudding. Whether or not they have had all contracts in the past year, I do not have in mind. That is of great significance to me as a measuring stick.

It is true that the British also have some contracts for the production of reactors. Personally, I do not fear in the least the situation where those produced by American manufacturers start operating in comparison to those produced by the British.

I do not know that any other country has had any success in building or in the sale of reactors outside their own territory, except Russia, which I understand has supplied reactors to Poland and some other country.

Representative HOSMER. That might not be necessarily under a free choice, free market basis, though.

Mr. MCCUNE. And that might be the understatement of the week.

Representative HOSMER. Thank you very much.

Representative DURHAM. Mr. Van Zandt?

Representative VAN ZANDT. No questions.

Representative DURHAM. Mr. Bates?

Representative BATES. Mr. Chairman, I would like to thank Mr. McCune for giving up his weekend and going with the committee to both Chicago and Detroit. He was very cooperative and responded to questions very forthrightly and answered all without evasion. I did not think at this stage I would have any more questions to ask him.

I would like to ask one question with reference to the protection against suits in the United States. Do you feel that that protection would mitigate against the sales of U.S. reactors abroad?

Mr. MCCUNE. No; I do not. I think it is unrealistic to believe—let me put it this way: Would it not be foolish for Europe to be making or putting a lot of efforts in the developing of a liability situation if the real purpose of the thing was to come over here and sue us in our courts?

Representative BATES. In reference to all your other comments, fuel cycle guarantee arrangements and declassification, cost accounting, licenses, of course, I think we should free ourselves of as much en-

tanglement and language prohibitions as time and circumstances will permit.

But it is your conclusion that we have reached a point where we could simply file a lot of these things so that the industry could move a little bit faster?

Mr. McCune. We have power reactor license No. 1. We have had, I don't know, 20-odd amendments to it. Very recently the Commission has given us the first broad license. The difference was: In the first license the thing was, "Tell us what you are going to do, describe it in detail, and as soon as we have approved it, you can do it."

We are now in a position where with certain limits the situation is, "Tell us what you are going to do and unless we tell you not to, you can do it." That is major progress.

All I am saying is if, in fact, we accelerate, as you gentlemen said you wished to do, the technical program and really get economic power within a reasonable period of time as I believe we can, let us not forget that these others must be accelerated and we must develop a system such that the nuclear power industry can be operated with no more severe regulatory penalty or chores than the existing industry; otherwise, we will have it technically, but it will cost so much administratively that we will not use it. That is all I am saying.

This does not mean that I am complaining about the job as of today, but it means that it needs careful watching. You cannot accelerate the technical without accelerating the rest of it and end up down the right road.

Representatives Bates. That is all. Thank you.

Representative Holifield. I had one other question.

On page 3 you mentioned the so-called capital contribution to plant cost, in the second paragraph. You said that any such contribution should be made on a basis which is equitable with all interested groups and on the basis which preserves some risk, and so forth.

In questioning Mr. McCone the other day in response to a question by Senator Anderson, I believe, he said that he would advocate up to 50 percent of the cost of the differential between a conventional fossil fuel plant and a nuclear plant, and that he would carry that 50 percent application up to the busbar, which would, in effect, include, of course, generating machinery as well as the nuclear power development machinery.

Senator Anderson brought out that if the Government did that much, and also furnished fuel at an advantageous cost, processed fuel at an advantageous cost, with free heavy water to those types of reactors that use heavy water, that there would be very little risk left in the project as far as private industry was concerned.

Do you have any particular comment to make on the formula which you think would be the right type of a formula?

Mr. McCune. If I understood the question correctly, you could almost paraphrase it by saying that if the Government gave too much there would be no risk left, and this I would agree to heartily.

I believe, and I believe fundamentally, that the present-day stations cost more than the conventional in almost all places. If we want to accelerate beyond the economic demand, that needs correction. This is the only way you will really ever get it.

I believe very strongly that the nature of what is needed in the way of help should come through the requirements or requests of the using industry, not through manufacturers.

In other words, I do not think we would have gotten the railroads across the West by giving a development subsidy to the manufacturers of locomotives. I am serious about this. I do not think we would get the maritime, assuming we wanted the maritime fleet today, I do not think we would get a maritime fleet by giving the research and development subsidies to manufacturers of propulsion equipment or steel plate.

Now, as to the amount of this that is required, as I see it, really, the full cost of the difference between the long term life—I am going to get in trouble with my language—the full difference between the total overall cost of a nuclear plant through its life and of equivalent steamplants would be an investment by the American taxpayer in our international position, or would be an investment by the American taxpayer in supplying a new source of energy and the Government could pay this full amount.

Representative HOLIFIELD. So you would extend assistance not only to the capital plants investments but to the operating cost penalty?

Mr. MCCUNE. No. I believe it is quite possible to produce plants today in which industry might well be willing to take the gamble that they can get the operating cost down, if the initial capital cost of the plant were reduced by an amount which you might consider America's investment in our international program.

I think really, the details of that—on that I would agree almost entirely with the testimony you have received in detail from Commonwealth Edison, from Mr. Gale. But I want to emphasize that I believe what you really want in this connection is the opinions of those who may or may not ask for help. That is the power industry. I do not think you are going to give any help to the manufacturing industry which would be effective in the area. A manufacturer just does not produce enough of this plant.

Representative HOLIFIELD. Well, whether it is the purchaser or the manufacturer who was the supplier to the utility, the end result would be a subsidy to private industry from the taxpayers' funds.

Of course, when we get into that sort of a field, we get into some complicated problems of subsidy and may have to do something because of international complications.

Mr. MCCUNE. The point I was trying to make, which I think you will agree with, is that in a plant such as Dresden or any of these plants, the amount of it that is actually produced in a single manufacturer's factory is extremely small. Probably overall, over half of the cost consists of earth moving, steel, sacked concrete, and the construction labor that goes to lay them down, which are the principal commodities, if you want to call them that, entering into plant cost.

You come back to just one man in the end and he is the man, generally, who is going to own and operate the station.

Representative DURHAM. Senator Hickenlooper?

Senator HICKENLOOPER. No questions, Mr. Chairman.

Representative DURHAM. Mr. Bennett?

Representative BENNETT. I have no questions.

Senator JACKSON. I have no questions.

Representative DURHAM. Thank you very much for your statement, Mr. McCune.

The next witness is Mr. Jack Busby, of the Pennsylvania Power & Light Co., Allentown, Pa.

STATEMENT OF JACK BUSBY, ACCOMPANIED BY W. E. JOHNSON, MANAGER, ATOMIC POWER DEPARTMENT, WESTINGHOUSE ELECTRIC CORP., PITTSBURGH, PA.

Representative DURHAM. Mr. Busby, I notice that you have quite a lengthy statement. Could you hit the highlights and then summarize your statement? Would that be agreeable to you? We can put the whole statement into the record.

Mr. BUSBY. Yes, sir, Mr. Chairman.

Sitting with me is Dr. Johnson of Westinghouse, who has been the project manager of the PAR project all through its activity.

Representative DURHAM. Very well. You may proceed.

Mr. BUSBY. As you know, we have appeared before the committee on prior occasions, in early 1957 and early 1958, to report on the status of the research and development program on the single region slurry homogeneous reactor. We appreciate the courtesy of the committee in appearing here today.

Representative DURHAM. We are always glad to have you, thank you.

Mr. BUSBY. This is really a further report in the context of these prior reports. As I am sure the commitee is well aware, on December 16 of last year, P.P. & L. and Westinghouse jointly announced the suspension of the PAR project for the reason that construction of a large-scale plant of the aqueous homogeneous type was not technically feasible at this time, in our combined judgments.

Inherent in this announcement is, of course, the basic fact that the project, the research program, had faced up to its first responsibility and had met its first purpose, which was a determination of technical feasibility or technical infeasibility, of a large-scale plant of this type.

With the decision so arrived at, we have stated that it was our conclusion that further research and development on this reactor type should certainly include prototype development and operating experience.

In this I think we are in complete accord with the conclusions independently reached by Dr. Weinberg of ORNL, as to which I think he went on record before this Joint Committee in response to the staff white paper toward the end of last year.

I think we are also in accord with the current thinking of the ad hoc committee of AEC. We would certainly make the point that the conclusion we have reached on technical infeasibility of a large-scale plant does not mean, by us, termination of interest in the homogeneous reactor, nor that there should be any termination of development of this reactor.

On the contrary, we believe that looking ahead to the future, this particular reactor type continues to have bright promise because of its simplified fueling, and because of its potentiality of high conversion of thorium to fissionable material.

In the interest of brevity, Mr. Chairman, and appreciating the time problem, let me skip directly, if I may now, because our purpose in appearing here today was to lay out on the table the main technical considerations and developments that led to our announced conclusion that a large-scale plant was technically infeasible at this time.

This is definitely an area not for my testimony at all, but for Dr. Johnson's. While we are both here to answer any and all questions, whether of a technical nature or otherwise, I think we will probably make the best progress by laying at least a summary of these important technical problems before the committee right now.

I would like to turn that over to Dr. Johnson.

Dr. JOHNSON. As I believe we have reported to this committee previously, the overall scope of the PAR project was the determination of the feasibility or lack of feasibility of proceeding immediately to the construction of the full-scale plant. The program that we initiated in January of 1958, after our previous 2½ years of work, had as its objective, the obtaining of additional information in those areas that appeared critical from this earlier work, and information that was necessary that we have in hand in order to make an adequate overall technical evaluation.

Major emphasis was placed on a few particular areas, but on a framework of an overall coordinated effort. Some of these areas include slurry handling and complex mechanical systems, corrosion erosion by high velocity slurry, reactor vessel hydraulics, recombination of radiolytic gasses, the effects of irridation on slurry properties, and problems of remote maintenance and plant layout.

I feel that during 1958 we made considerable progress in most of these areas, and while much of the information that we obtained was encouraging, this certainly was not true in all cases. By late 1958 it became apparent that in several of these important areas, we were not obtaining the information at a rate sufficient to obtain the objectives of the 1958–59 program.

In addition, it appeared that there was essentially nothing that could be done to correct this. These problem areas have been discussed in detail in an article that was written by myself and Mr. Stanley Townsend, of the Pennsylvania Power & Light Co., and published in the February issue of Nucleonics magazine. I would like to summarize very briefly the major points that we made and I am prepared to discuss these as fully as you would like, if you like.

Representative VAN ZANDT. Would the doctor object if at this point in the record we insert the article he mentioned a moment ago written by him and Mr. Townsend?

Dr. JOHNSON. I certainly have no objection.

Representative VAN ZANDT. I have a copy of the article which in my opinion is much broader than your statement, and for that reason I believe it would be good information for the record.

Representative DURHAM. Without objection, it will be inserted into the record.

(The document referred to follows:)

[Reprinted from Nucleonics, February 1958]

On December 16, 1958, the Pennsylvania Power & Light Co. and Westinghouse Electric Corp. announced the suspension of the Pennsylvania advanced reactor project (PAR) because construction of a large-scale aqueous homo-

geneous plant was technically infeasible at that time. It was recommended that prototype plant development and operating experience should be part of further development of the PAR reactor type. A brief résumé of the accomplishments of the project and the reasons which led to its suspension are set forth below.

The PAR project was initiated in 1955 as a research and development program entirely supported by private funds. The program was to determine the feasibility of a full-scale homogenous plant in the 150 Mw(e) size range, with and 80 percent plant availability factor. The initial expectation was that 2½ years of research, plus the knowledge to be gained through the homogenous development work then underway at Oak Ridge, would produce enough information by the end of 1957 to determine feasibilty and to provide a basis for a prudent decision on the building of a large-scale plant.

However, by the end of 1957 sufficient data had not been obtained to make a decision on plant construction, despite project expenditures of $5.5 million. It was therefore felt necessary to extend the program. The atomic Energy Commission was asked to provide $7 million for future research and development during 1958–59, with final disposition to depend on the outcome of the 2-year development program and the decision about building a large-scale plant. This arrangement was subsequently accepted by the Commission and approved by the Joint Congressional Committee on Atomic Energy. A central feature of this project was that it should be possible to determine technical feasibility in time to permit completion and initial operation of the full-scale plant by the end of 1963. The arrangement expressly provided that either the Commission or the companies could terminate the project for any reason prior to the end of the 2-year period.

However, contractural negotiations with the Commission had not been completed as of the suspension date, so all expenditures in 1958 were paid by Westinghouse and P.P. & L. (with Baltimore Gas and Electric Co. participating) making their aggregate cost for the project to date approximately $9 million, about 40 percent of which was for materials and equipment specifically designed for the project. The major part of the remaining cost was for payroll; there were 115 persons directly engaged in the project at the time of suspension, of whom 70 were engineers and scientists.

Why the PAR Homogenous Project Was Suspended

(By W. E. Johnson, manager, Atomic Power Dept., Westinghouse Electric Corp., Pittsburgh, Pa., and S. C. Townsend, manager, Atomic Engineering Department, Pennsylvania Power & Light Co., Allentown, Pa.)

[Figures 2 and 3 referred to in this article were not reproduced]

The Pennsylvania advanced reactor (PAR) project, started in 1955 by the Pennsylvania Power & Light Co., and Westinghouse Electric Corp., was directed at the building of a single-region aqueous homogenous reactor. During the 3½ years the project was active, important progress was made toward the solution of many of the problems faced in the construction and operation of this type of plant and of fluid-fuel reactors in general. Much of this has been described elsewhere (1–4). What follows: are highlights of developments that influenced the decision to suspend work on the project.

At the inception of the PAR program, the existing work then underway at the Oak Ridge National Laboratory was evaluated. With the success attained by the HRE–1 and the construction program then underway for HRT (a two-region machine with a solution core and a slurry blanket). It was considered that successful operation of HRT, in combination with PAR research and development, could reasonably be expected to produce information that would allow scaling up to a full-sized plant.

As time has passed, the feasibility of going directly to the full-scale plant has decreased. The HRT program did not progress at the rate initially planned and the slurry blanket was never operated. At the same time, while no single problem facing the PAR slurrry reactor appeared unsolvable, there remained many problems for which complete solutions had not been worked out. This multiplicity of uncertainties in important areas of research, made increasingly critical in view of project time limitations made doubtful the achievement of the contemplated 80 percent availability factor. This led to the conclusion that the construction at this time of a large-scale homogeneous plant of the PAR type was not technically feasible.

The reactor cycle that was the focus of the PAR experimental and design studies is shown schematically in figure 1. It is an aqueous homogenous system based on the thorium-uranium cycle. The primary system generates 550 Mw (th) in a 12¼-ft-o.d. single-region spherical vessel through which flows a suspension of oxides of thorium and uranium in heavy water. The flow rate is 32,000 g.p.m.; inlet and outlet temperatures are 465° F. and 580° F., respectively; and, primary system pressure is 2,000 p.s.i. Upon leaving the reactor vessel the floor divides into four 16-inch loops, shown as one in figure 1, and gives up its heat in four 10,000-foot²-steam generators, one in each loop. Steam is generated on the secondary side at 400 p.s.i.a; electrical output is 150 Mw. The proposed plant comprises in addition: a gas-handling system, a fuel-handling system, an integrated on-site chemical processing system, and a "hot shop" for the remote maintenance and repair of components.

Based on present-day costs of fissionable material and heavy water, a plant such as this attains maximum fuel-cost economy at a Th concentration of about 300 gm/liter and a U^{235} concentration at startup of about 10 gm/liter. The U^{235} concentration decreases with time and that of U^{233} increases; the net conversion ratio at steady state is about 0.86. Higher conversion ratios can be attained in such a system by the use of higher concentrations of Th and U and a larger reactor core, but at greater cost. At some future date economies will justify the building of a breeder reactor, but for the near future, the single-region plant is a logical step in the development of a technology that could lead to a two-region breeder reactor.

Because of the reactor's inherent advantages, the decision to drop the project was made only after careful consideration. During 1958 regular quarterly reviews were conducted on the status of the project work and other related developments, and it was as an outgrowth of these reviews that the conclusion was finally arrived at that the project would be suspended.

The seven major problems existing at the end of 1958 along with some indication of the progress made toward their solution are detailed below.

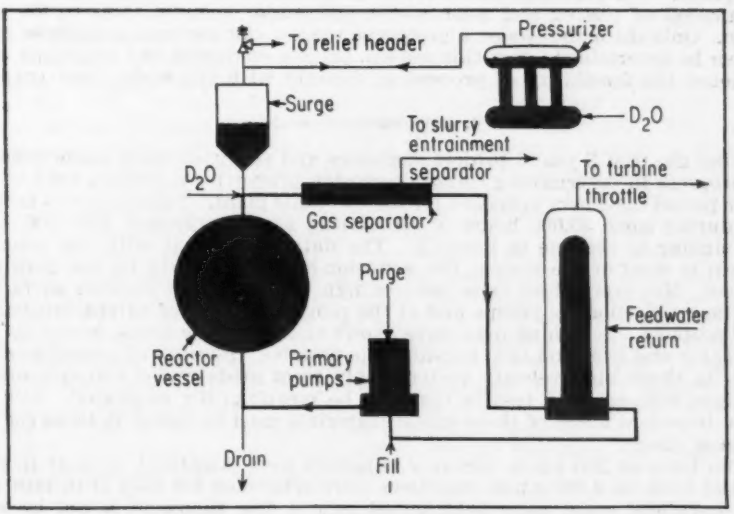

FIGURE 1. Simplified flow diagram of PAR primary system.

1. GASEOUS RECOMBINATION

In aqueous slurry fuel reactors, heavy water decomposes radiolytically into deuterium and oxygen and must be recombined for both economic and safety reasons. This can be done either by a catalyst in the reactor system, or by external catalyst beds. In all early designs for PAR, internal recombination was preferred, based on the assumption that if a suitable catalyst was not found, an external system could be used. In these design studies costly and complex auxiliary systems were required to prevent the accumulation of explosive gas

mixtures in the external recombiner. As a result, it was concluded that a suitable internal catalyst must be found and thoroughly evaluated before proceeding to a full-scale plant. Some catalyst materials show promise, but uncertainties about the effects of irradiation, corrosion products, and long-term hydrothermal treatment on the properties of these catalysts are great enough to preclude building a full-scale plant.

2. EFFECTS OF IRRADIATION ON SLURRY PROPERTIES

Much more information about the irradiation effects on the properties of slurry fuel and on additives (such as the catalyst) was needed before deciding to proceed with construction. To obtain this information, the PAR project entered into a joint program with the Oak Ridge National Laboratory to carry out such work in the new Oak Ridge research (ORR) reactor. Figure 2 shows the first PAR project in-pile slurry test loop, which was to be followed by a series of similar loops. This loop was originally scheduled for operation in the ORR reactor in March 1958, but due to technical difficulties and schedule delays, it will not be operated before mid-1959. A program review made it clear that the amount of data available by the end of 1959 from this joint program, even with one or two added test loops, would not be sufficient to recommend full-scale plant construction.

3. REACTOR-VESSEL HYDRAULICS

The reactor vessel must be designed to insure uniform distribution of slurry in the vessel and to cool the thermal shields. Progress was made toward the solution of the problem of slurry distribution in the vessel itself. A series of low temperature tests was performed, not only with slurries of thoria but also with low-temperature suspensions of glass beads which simulate the high-temperature settling rates of thoria. The results of these tests were to be verified in a high pressure, 4-foot vessel to be installed in loop D (figure 3).

Cooling of the thermal shields proved to be a bigger problem than originally anticipated. Several methods have been proposed, but each requires a considerable amount of testing and some would add major complications to the plant system. Only through tests on a prototype reactor can the true magnitude of the problem be determined. For this reason, project engineers and scientists again questioned the feasibility of proceeding directly with full-scale plant construction.

4. CORROSION-EROSION

During the past 3 years, project engineers and scientists have made considerable progress in determining corrosion-erosion properties materials used to contain or propel the slurry proposed for the full-scale plant. This data was accumulated during some 30,000 hours of circulating slurries through four 200 g.p.m. loops similar to the one in figure 3. The data shows that with the velocities attained in most of the system, the corrosion-erosion rate will be less than 1 mil per year. However, where velocities are high, such as on the impeller surfaces of the primary circulating pumps and at the plugs and seats of valves, erosion is a major problem. Screening tests have shown that for these areas, materials such as Zircaloy and titanium hold considerable promise. Because of special flow conditions in these high velocity regions, only tests made under actual operating conditions will produce results that can be meaningfully evaluated. For this reason, impellers made of these exotic materials must be tested in loops for long periods of time.

Initial tests on 200 g.p.m. Zircaloy impellers were scheduled to start in early 1959 and tests on 4,000 g.p.m. impellers were scheduled for loop D in late 1959. These impellers could have been tested only a few thousand hours by early 1960. The testing of valves of designs similar to those required for the final plant got underway in early 1958. Results have not been encouraging. While test programs on impellers and valves could and would have continued in parallel with plant construction, the amount of pertinent information available by early 1960 would have been extremely limited.

5. STRESS CORROSION

The project has, in the course of operation of the 200 g.p.m. loops, experienced a number of small high pressure leaks that resulted from stress corrosion. In general, these leaks developed when the slurry was permitted to lie stagnant

for long periods. Design of later loops eliminated most of these stagnant areas and the thorium oxide preparation was closely controlled to minimize the chlorides present as contaminants. As a result, chloride stress corrosion has not been encountered in the most recent test operations. There exists, however, a distinct possibility that an operating error, or the accumulation of slurry deposits, could initiate such troubles in the plant. Because the presence of decay heat in irradiated slurry could have an effect on the buildup of such deposits, meaningful information should be obtained through the operation of a prototype reactor at power densities comparable to that proposed for the full-scale plant.

6. REACTOR STARTUP

A problem recognized early in the course of the design studies was that of startup of a slurry reactor, and particularly, startup after an emergency shutdown during which solids were permitted to settle in the primary system. A number of methods were proposed to handle this problem and some seem feasible, and nonnuclear tests of some of these methods were planned. Calculations show that complete safety can be obtained without the use of external reactivity control such as control rods or reflectors; yet the importance of this problem was one of the factors contributing to the decision against building a large-scale plant at this time.

7. PLANT LAYOUT AND MAINTENANCE

Problems associated with the maintenance of a fluid fuel reactor plant led to the choice of an all-welded plant, one in which equipment requiring maintenance would be removed by remote means and repaired in an associated "hot shop."

The layout of equipment for remote maintenance caused an increase in the physical size of the plant beyond anything previously expected. In most of the problem areas, answers can only be found through operation of a reactor plant having contamination levels similar to those in a full-scale plant. The extent to which contamination is spread throughout the plant when a component is removed from the system can only be found through the operation of a prototype, although successful techniques for handling such matters have been developed in operating plants such as the HRT, but at the expense of considerable down time. To use a full-scale power generating plant to develop decontamination techniques appears uneconomical and unwarranted. The writers' present outlook for such a project as PAR has obviously undergone considerable change as the research and development work has progressed from 1955 to date. It has been just this research and development which has produced the appraisal of the cumulative difficulties and uncertainties described in this article.

All of the problems that have been discussed are believed to be solvable with adequate time and effort. Certainly measurable savings in time and a greater assurance of reliability can be obtained by first proceeding with the design, construction, and operation of a prototype. Such prototype should be of sufficient size to produce information that could be extrapolated directly to a full-scale plant of 150 Mw(e) or larger. But there remains a basic question to be answered: What development pace should now be set for the homogeneous reactor within an overall nuclear power development program? Many elements are involved requiring most careful and thoughtful consideration because of the various changes in circumstances since mid-1955. Westinghouse and P.P. & L. interest in the homogeneous reactor will continue; therefore, we consider that the PAR project has only been suspended.

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Dr. JOHNSON. One area is that of gaseous recombination, that is, the recombination of the deuterium which has been decomposed by

radiation in the reactor. In this area we found some possible catalyst materials that showed promise, but the uncertainties about the effects of irradiation, corrosion products addition, and long-term hydrothermal treatment on the properties of these catalysts were great enough to preclude making a decision on the building of a full-scale plant.

On the effects of irradiation on slurry properties, we carried out a very intensive program review and found that the amount of data available or that would be available by the end of 1959 from the PAR Oak Ridge joint in-pile program, even with one or two added test loops, would not be sufficient.

In the area of reactor vessel hydraulics, it became evident in mid-1958 that the problems of reactor vessel hydraulics and the cooling of the thermal shields would require high temperature testing that could not have been completed by the end of 1959.

A major problem area is that of corrosion and erosion. The problem of erosion of materials in high velocity areas proved considerably more difficult than anticipated, and resulted in essentially complete destruction of pump components in only a few hundred hours.

We have included in our formal statements to you photographs of such components.

I have here in front of me, because I believe it is much more striking than the photographs, a typical sample of the magnitude of the problem we have encountered in this area. I might say that with the facilities we have developed in the PAR program, this is the only place where results on pieces this large could be obtained in the entire atomic energy program.

Representative HOSMER. What is that impeller constructed from?

Dr. JOHNSON. This particular impeller is type 347 stainless steel.

Representative HOSMER. That is a good, tough material.

Dr. JOHNSON. This is a good, tough material and our problem is a problem of erosion in very high velocity areas.

Representative DURHAM. How long was that exposed?

Dr. JOHNSON. This particular piece was exposed for about 1,300 hours.

The second sample, and there are only two, was in essentially the same condition after only 700 hours, and in this particular case was a sample where we had expected very improved results over this piece. Our results proved diametrically opposite.

Representative HOLIFIELD. What was the original shape of these sections? Were they quite a bit bigger?

Dr. JOHNSON. They were quite a bit bigger and came out to be a straight edge. There is a photograph in the formal report showing it in the before condition as well as this one.

Representative VAN ZANDT. Is this sample No. 1?

Dr. JOHNSON. This is sample No. 1. Sample No. 2 has not yet been decontaminated. From this sample, No. 1, we actually had 1,300 hours, part of that being water operation.

Representative VAN ZANDT. Using the same material?

Dr. JOHNSON. On the second sample we had 700 hours, using the same material but what we thought was better hydraulic design. I might say that in the small size impellers in which we have thousands of hours of experience, we had no reason to believe it would be as difficult as this.

Representative HOLIFIELD. This is a good demonstration of the fact that you cannot extrapolate from a small model to a larger operating mechanism accurately.

Dr. JOHNSON. We feel there is not enough information in many areas today to be able to extrapolate from small size to full size.

Representative HOSMER. If you had an impeller half that size and ran it in the same solutions, you would have your corrosion-erosion effect?

Dr. JOHNSON. This is correct. The impellers we have tested for thousands of hours have a capacity of one-twentieth of this. This particular impeller is the largest that has ever been tested, serves a 4,000-gallon-per-minute loop, and is half of the size that we would have proposed in the full-scale plant.

Representative VAN ZANDT. Your problem also extends itself to other areas of the reactor where the slurry comes in contact with metals?

Dr. JOHNSON. It extends itself to those areas in which we have very high velocity of the slurry. In the general piping, in most of the components, we feel we have this problem well in hand. It is only in those areas where we obtain velocities in excess of 50 or 60 feet per second that we run into major problems of the magnitude we are talking about.

Representative VAN ZANDT. In general, it is a metallurgical problem?

Dr. JOHNSON. A metallurgical-chemical, engineering-hydraulic problem.

Representative HOLIFIELD. Going back to the original question, I think it is very important that we understand the answer from a scientific standpoint. When you are operating any type of a mechanism under conditions of less speed, less velocity and so forth, than you would in your larger operation, you cannot extrapolate accurately the results of your smaller experience?

Dr. JOHNSON. I think my answer must be qualified that this depends upon the particular area in which you are talking. In our small impellers that we tested successfully, the velocity at this particular point was comparable to that of the second large-scale impeller that we tested and, as a result——

Representative HOLIFIELD. Was the second large-scale impeller the same size as the first?

Dr. JOHNSON. The same capacities, different hydraulic design, but essentially physically the same size.

Representative HOLIFIELD. The same quality of material?

Dr. JOHNSON. The same quality of material. In the second impeller, we believed firmly that the hydraulic design was such as to give us velocities that were comparable to those in the small impellers.

As a result, we did not expect the serious deterioration that we got. The problem in this particular area is that techniques are not developed to accurately determine the velocities in a complex shape as this.

Representative HOLIFIELD. Then your statement on page 6 about it now appearing that a very substantial amount of research work, including construction and operation of a prototype, remains to be done, is based on the fact that you must build the prototype in order

to get the information you want on the experimental research and development data.

Dr. JOHNSON. In some particular areas this is true, and there are enough of these areas in our opinion to now say that it is not feasible to go directly to the large-scale plant.

Representative DURHAM. All areas of a plant like this have to function?

Dr. JOHNSON. Yes; that is exactly the point.

Representative HOLIFIELD. So if there is any part of the development which needs actual operation of a pretty good-sized prototype, you have to have that. You cannot substitute it in a laboratory without taking a gamble.

Dr. JOHNSON. That is exactly correct. We say that in some areas, in fact in most of the areas, we felt that we could get satisfactory information directly in the laboratory. In this particular area, given enough time, I feel we can solve this problem in the laboratory. In other areas, such as the catalyst area that I mentioned earlier, and the effects of irradiation on slurry, I do not believe we can get adequate information without reactor operation.

Representative VAN ZANDT. Doctor, have you gained a lot of experience in the technique of operating the reactor under water?

Dr. JOHNSON. I think we, early in the program, determined that it was not possible to extrapolate the underwater techniques of, say, the homogeneous reactor tests to large-scale operation. This, I believe, is a type of extrapolation that you can make without a prototype. It just takes analysis of construction techniques.

Representative HOLIFIELD. Does this revolve at high speed?

Dr. JOHNSON. This particular piece revolves at 1,800 revolutions per minute.

Representative HOLIFIELD. Does that necessarily pump the slurry through the system?

Dr. JOHNSON. Yes; this is a relatively low-speed impeller as impellers go. It was designed specifically to try to minimize these effects.

Representative VAN ZANDT. In general terms, can you tell us some of the benefits resulting from this period of research and development?

Dr. JOHNSON. I think it would take a long time to list all of these. I think one basic contribution we made is that we put together in a self-consistent form information for the first time that would allow us to adequately compare this reactor type with other reactor types that are being proposed.

I think we did this on both a technical and on a practical basis. We can stand here today and discuss the potential problems of this reactor type in a way that it was not possible to do even a few months ago.

Representative DURHAM. You did learn a lot.

Dr. JOHNSON. As I say, if I were to take the time to list all of the areas where I think we made positive contributions, I am sure your time limitation would run out quickly.

Representative DURHAM. Well, you have learned from your study so far that this is not feasible to go ahead with, because you do not really have enough information.

Dr. JOHNSON. That is right. I think we have gone to the point where it is clear to us that we did not have enough information and we could not expect to obtain enough information in the year left before we had to make a decision to warrant going forward.

Representative VAN ZANDT. What is being done with all the laboratory equipment you had at Pittsburgh?

Dr. JOHNSON. All of this equipment which has any general purpose, which is, I would say, perhaps a quarter of the total investment, is being put in the condition where it can be used on other projects.

A major part of the equipment was very special equipment which was devoted essentially to this type of work and does not have general applicability. This equipment is now in the process of being decontaminated to the point where it can be disposed of in whichever way it can.

With respect to the inpile test equipment which we were developing jointly with Oak Ridge, we have made a decision to contribute this equipment to Oak Ridge National Laboratory so they can continue this work as the program continues.

Representative HOSMER. The knowledge that you have picked up is also being of help to Oak Ridge in solving the same problem?

Dr. JOHNSON. All of the information that we have developed has been made immediately available to Oak Ridge Laboratory on both a monthly and a quarterly basis and on an informal basis through very many meetings between the organizations.

Representative VAN ZANDT. Is your company represented on the AEC panel evaluating liquid fuel reactors?

Dr. JOHNSON. We have a full-time consultant, not an official member. He was my technical assistant during the life of the PAR program. I, and several of my supervisors, made a full-day presentation to this committee on the results of our program and have made available to them any information that they have asked for.

Representative DURHAM. Are there any further questions?

Senator JACKSON. I have just one question.

How much money have your companies spent?

Dr. JOHNSON. On the entire program?

Senator JACKSON. Yes.

Dr. JOHNSON. By the time we will have terminated the work, which will be about the middle of March, we will have spent somewhere between $8.9 million and $9 million.

I might say that we are terminating this program in a logical way in which we are writing up, in finished form, all of the work that was in progress so that if there is a need to start this type of work again we have a starting point in a clear, concise form.

Senator HICKENLOOPER. Dr. Johnson, perhaps you have stated it, but what do you find now as the chief impediment here, the factor that raises your biggest problem in using these slurries? Is it corrosion? Is it sedimentation? Is it improper reaction?

Dr. JOHNSON. It is hard to pick a particular reason and say, "This is it." I think the general areas that we outlined in some detail in the article gives as concise an answer to that question as we can give.

If you did ask that I pick one particular item for making the determination that we could not build a full-scale reactor at this time, it would be the catalyst problem. In previous presentations to this

committee, we pointed out, I believe, that there were two ways of recombining this gas.

One was internally, in the reactor; and the other was by essentially conventional equipment outside of the reactor.

One of the basic pieces of information which has been developed during 1958, developed jointly by Oak Ridge and ourselves, is that when we are handling gases of the quantity that you would get in a large-scale reactor, safety will require that you do this internally, and, therefore, you must develop a catalyst.

We feel strongly that this cannot be done without reactor operation in a small-scale reactor first. Any of you who are familiar with the art of catalysis, I do not think it is a science, will understand that statement.

Senator HICKENLOOPER. Thank you.

Representative WESTLAND. As I understand it, you have spent about $9 million in this project. You have written it off and you are through; is that correct?

Dr. JOHNSON. I think as far as doing any more active work, the answer is yes, we are through. I think that in talking for Westinghouse, the information that we have developed and the know-how that we have developed, and the evaluation that we have made between this reactor and other reactor types, is of continuing value to us.

Certainly, we have information and know-how to continue this type of work on any scale that is determined to be the right scale as a result of the reviews of fluid fuel reactors that is now being carried out.

Representative WESTLAND. Do I understand correctly that this is the case, that you have stopped this because of the time element, because things have not developed as quickly as you had hoped they would, or is it because the problem is, in your opinion, insoluble?

Dr. JOHNSON. I think we have stated in the document that we have presented to you that we feel that all of the problems that we are facing are soluble with enough time and effort.

On the other hand, we also feel that the time and effort that would be required must be evaluated in terms of where this reactor fits in the overall reactor picture before such effort is actually expended.

Representative WESTLAND. Let me ask you this question: In the final analysis, and if this were finally a successful operation, at about what price would you expect to produce the power?

Dr. JOHNSON. This, of course, is a very, very difficult question to answer. I think the only answer I can give, and I must say this is a very tentative answer, is that the economic analyses that we have made for the first reactor of this type would produce power in the order of 10 mills per kilowatt-hour if we could attain a plant availability factor of 80 percent.

I want to reemphasize the last statement—if we could attain a plant availability factor of 80 percent.

The unknowns with respect to down time, plant down time, in a reactor of this type, are so great that there is no assurance of what the plant availability factor would be.

This would be the major contributing factor in determining what the cost of the power would be.

Representative WESTLAND. But if you had your 80 percent, it would be around 10 mills?

Dr. JOHNSON. For the first reactor plant, based on the estimates we have made, jointly with Stone & Webster, we would estimate that the cost would be about 10 mills per kilowatt-hour.

Representative WESTLAND. Do I also understand that you do not recommend a prototype on this basis?

Dr. JOHNSON. I believe our recommendation is that if there is to be continuing development effort on this kind of reactor, that this should include the development of a prototype before going to a full-scale plant.

I think the answer to the question of "should there be continuing development on this kind of reactor," should come from the fluid fuels task force which is now in session reviewing this particular point.

Mr. BUSBY. I would like to add a comment in line with the question that Congressman Westland asked about costs.

This piece of equipment here, of course, has to be considered in the context of a system that is very hot, and has to be maintained remotely. This is not a quick automobile repair job. This, therefore, focuses attention very sharply on this matter of 80 percent plant availability.

Since it is the kind of a plant where its ultimate advantage is in terms of a low fuel cost, another way of saying it is that it is also a plant that has a very high capital cost and, therefore, also very high annual carrying charges, and if it is not going to operate pretty much around the clock, then the cost in mills per kilowatt-hours skyrockets very quickly.

Representative DURHAM. Are there any further questions?

If not, thank you very much.

(The statement of the Pennsylvania Power & Light Co., and Westinghouse Electric Corp. follows:)

REPORT ON THE SINGLE-REGION HOMOGENEOUS SLURRY POWER REACTOR PROJECT—PAR

Pennsylvania Power & Light Co., and Westinghouse Electric Corp.

INTRODUCTION

On February 26, 1957, and again on February 25, 1958, statements were submitted to the Joint Committee on Atomic Energy on the objectives and progress to date on the single region homogeneous slurry power reactor project—generally known as the PAR project. On December 16, 1958, the Pennsylvania Power & Light Co. and Westinghouse Electric Corp. announced the suspension of the Pennsylvania advanced reactor projects (PAR) for the reason that construction of a large-scale plant of the aqueous homogeneous type was technically infeasible at that time. With this decision it was recommended that prototype plant development and operating experience should be obtained as part of any further development of the PAR reactor type. It is the purpose of this statement to outline the progress that was made during the past year and to discuss in some detail the reasons that led to the decision to suspend work on the project.

At the outset, let us reemphasize our belief that this reactor holds bright promise for the future, due both to its simplified fueling and potentiality of high conversion of thorium to fissionable material.

The PAR project was initiated in 1955 as a research and development program entirely supported by private funds. The objective of the program was to determine the feasibility of a full-scale homogeneous plant in the size range of 70,000 to 150,000 electron kilowatts with reasonable prospects of achieving an 80-percent plant availability factor. The initial expectation was that 2½ years of research, plus the knowledge to be gained through the homogeneous development work then

underway at Oak Ridge, would produce information by the end of 1957 adequate to determine feasibility and to provide a basis for a prudent decision on the building of a large-scale plant.

However, sufficient data had not been obtained by the end of 1957 to make a decision on plant construction, although project expenditures by that time had amounted to $5.5 million. It was therefore felt necessary to extend the program. The Atomic Energy Commission was asked to provide $7 million for future research and development during 1958–59, with final disposition to depend on the outcome of the 2-year development program and the decision about building a large-scale plant. This arrangement was subsequently accepted by the Commission, approved by the congressional Joint Committee on Atomic Energy, funds authorized by Congress, and definitive contract negotiations well advanced but not completed as of the suspension date. A central feature of this project was that it should be possible to determine technical feasibility in time to permit completion and initial operation of the full-scale plant by the end of 1963. The arrangement expressly provided that either the Commission or the companies might for any reason terminate the project prior to the end of the 2-year period. As a result, all expenditures in 1958 have been paid by Westinghouse and P.P. & L. (with Baltimore Gas & Electric Co. being a participant), making their aggregate cost for the project to date approximately $9 million, about 40 percent of which was for subcontracts, materials, and equipment specifically designed for the project. The major part of the remaining cost was for payroll, there being a total of 115 persons directly engaged in the project at the time of suspension, of which 70 were engineers and scientists.

SCOPE OF PROJECT—1958 PROGRAM

The overall scope of the PAR project has been discussed in considerable detail in previous statements submitted to this committee. For the past year the objective has been to determine the technical feasibility of building a large (70,000 to 150,000 electric kilowatts) single region aqueous homogeneous reactor powerplant. The feasibility was to be determined from the results of an extensive research and development and engineering program carried out at the PAR laboratories in the Westinghouse Atomic Power Department at Pittsburgh, Pa., and from careful continuous evaluation of all pertinent work being carried out elsewhere, particularly at the Oak Ridge National Laboratory, but also at Hanford, Savannah River, and the National Reactor Test Site.

Results of the first 2½ years of the PAR development program, that is, through December 1957, were presented to this committee last year. A very brief review is warranted here. Extensive experimental facilities were designed, installed, and used to obtain firsthand experience in the problems of slurry handling, erosion-corrosion by slurries, component development, and remote maintenance. Two plant designs were completed; the second of these was in enough detail to give a much more realistic cost estimate for such a plant. Based on the information obtained from the experimental program and from the nuclear calculations on the overall fuel cycle, preliminary estimates of power costs from such a plant were prepared. While these estimated costs were much increased over those estimated at the beginning of the project, they were still encouraging enough to warrant further investigation of this type of plant, particularly when considered with respect to the longer term problem of decreasing availability of U–235 and the need to utilize the available supplies of fertile materials.

The overall results of the project were summarized for you last year as follows:

"* * * Now after 2½ years we recognize that although the project has made significant progress, certainly it cannot be said that the feasibility of this type plant has yet been established. The state of the art has not been developed to the point where a prudent decision could be made today to commit the building of a plant either from a technical or an economic viewpoint.

"* * * Looking to the future we continue to believe that this type of plant shows good economic promise and that the current program should be continued. We have estimated that 2 additional years of work and a cost of $7 million should be sufficient to obtain the necessary information to permit a prudent decision in undertaking construction of the plant. However, we believe we should point out that the nature of this development program is such that both substantial difficulties and uncertainties are inherent in it, and changes in this schedule could become necessary."

The program initiated in January 1958 had as its objective obtaining sufficient information in those areas which appeared critical from the earlier work. The program was prepared in such a way as to give an overall coordinated effort. The major emphasis, however, was placed on a few particular areas: slurry handling in complicated mechanical systems, corrosion-erosion by high-velocity slurries, reactor vessel hydraulics, recombination of radiolytic gases, effects of irradiation on slurry properties, radioactive off-gas disposal with the associated problems of safety and site selection, and remote maintenance and plant layout. These were the areas where considerably more information was needed before any technical evaluation could be made of the feasibility of continuing at all let alone proceeding on the very tight schedule of plant completion proposed.

In parallel with these activities the Pennsylvania Power & Light Co. proposed to actively investigate potential plant sites and conduct a continuous review program of site data with the AEC.

SUMMARY OF PROGRESS SINCE THE SECTION 202 HEARINGS IN 1958

Considerable progress was obtained in each of the above listed areas during the past year. Not all of the information obtained was encouraging.

Slurry handling

At the time of our last report, we had just placed in operation our new major test facility known as loop D. Loop D is a high temperature and pressure circulating slurry loop made of 10-inch diameter stainless steel pipe and having a flow rate of 4,000 gallons per minute, one-half of that proposed for each loop in the full-scale plant. During the past year we had added to this loop most of the auxiliary systems needed for a full-scale plant. These included a high pressure letdown and makeup system for adding or removing slurry from the system, a slurry concentration system for varying in a controlled manner the concentration of the slurry in the loop, and a high pressure drain system for carrying out simulated emergency drains that might occur in a full-scale plant. Also added to the basic loop was a special valve test system for evaluating full-scale valves and valve actuators. Appendix A includes a photograph of the drain tank being lowered into place and gives a feel for the size of equipment being used in these tests.[1] Also included are two photographs of loop D. One is a duplicate of that submitted with our statement last year showing the status of the loop at that time, and he other shows the loop as it appears today with the auxiliary systems added.

Operation of this loop from a slurry handling and systems development point of view looks generally encouraging. As discussed later, however, major problems of erosion became apparent in the valves and in the slurry circulating pump impellers. In addition, it became apparent that the technology of specifying a slurry having particular handling properties was not yet sufficiently developed to be able to extrapolate from small-scale preparations of a few hundred pounds of oxide to larger scale preparations of a few thousand pounds. There also was considerable uncertainty as to the effectiveness of the quality control measures needed to produce specification-grade materials.

Procedures simulating the startup and shutdown of a slurry reactor plant were carried out successfully. The concentration of the slurry was varied from essentially pure water to full-plant design concentration.

One high temperature and pressure drain test was completed. About 60 percent of the solids were drained from the system during this test. While these results were obtained from a single test and while we feel strongly that the residual solids could be reduced appreciably in successive tests, we feel we have verified that a major effort would have to be devoted to developing methods of removing the residual solids before the plant could be restarted in a completely safe manner. The amount of these remaining solids also brought into clearer focus the problem of residual radioactive decay heat with the attendant problem of removal of this heat to prevent any possible fusing of the slurry particles into a solid glasslike mass or to prevent the possible buildup of temperatures that could result in damage to some of the equipment. True evaluation of the seriousness of this latter problem can only be obtained through the irradiation of large masses of materials for long periods of time.

[1] EDITOR'S NOTE.—Appendixes A through F, containing photographs, are on file in offices of the Joint Committee on Atomic Energy.

At the time the project was suspended two major components were on order to be added to loop D in early 1959. The first of these was a 4-foot diameter high pressure prototype reactor vessel complete with one thermal shield and with a four-inlet nozzle assembly. The second was a 200-tube experimental steam generator.

Corrosion-erosion

One of the basic problems of slurry-type reactors is the erosivity of the slurry fuel. During the life of the PAR project, considerable progress was made in determining the corrosion-erosion properties of various materials used to contain or propel the slurry proposed for the full-scale plant. These data were accumulated through tens of thousands of hours of circulating slurries in high temperature and pressure loops and show that with the velocity obtained in most of the system the corrosion-erosion rate will be less than 1 mil per year. This is a very acceptable rate for a plant of this type. However, where velocities are high, such as on the impeller surfaces of the primary circulating pumps and at the plugs and seats of valves, erosion is a very major problem. Appendix B [1] shows before and after photographs of the two sets of hydraulic parts used in the main circulating pump in loop D. In both cases, these parts were essentially totally destroyed in approximately 1,000 hours of service. The deterioration of the first set of parts, while discouraging, was not considered too serious since it was recognized that the design was such as to result in very high velocities in certain regions. In the second case, however, the parts were designed to limit the calculated velocities to values similar to those used in smaller pumps where exceedingly encouraging results had been obtained. Deterioration of this second set of parts after only 700 hours of slurry operation was extremely discouraging. These results show that because of the special conditions of flow that occur in these high-velocity regions, calculated velocities alone cannot be used for evaluating the erosion problem, and tests must be made under actual operating conditions to produce results that can be realistically evaluated.

Tests in our smaller loops have shown that for high-velocity areas, materials such as zirconium and titanium hold considerable promise. Impellers made of these more exotic materials were scheduled to be tested for long periods of time starting in early 1959 on our 200-gallons-per-minute loops, and in later 1959 on loop D. These impellers could have been tested only a few thousand hours by early 1960.

The testing of valves for controlling flow, using designs similar to those required for the final plant, got underway in early 1958. Results obtained up to the time of the suspension of the project were far from encouraging.

Reactor vessel hydraulics

Physics considerations require that the slurry fuel in the reactor vessel be uniformly distributed throughout the entire vessel. In addition, several thermal shields are required in the vessel to reduce the thermal stresses induced by reactor operation. The shields in turn must be adequately cooled to remove the heat that is developed in them. Determining the proper hydraulic design of the reactor vessel to insure such uniform distribution of slurry and to adequately cool the thermal shields has always been recognized as an important and difficult program.

The basic information needed for such design was not available and had to be determined experimentally. The problem was initially studied through the use of a small-scale low temperature and pressure model having a diameter of 18 inches. During the past year, two new facilities were designed and placed into operation to help solve this problem (appendix C).

The first of these was a 2,500-gallon-per-minute low-temperature low-pressure test loop incorporating a 3-foot diameter scale model of the reactor vessel. A series of low-temperature tests were performed not only with slurries of thoria but also with suspensions of glass beads which simulated at low temperature the high-temperature settling rates of thoria. The result of these tests were to have been verified at reactor design temperatures in the high-pressure 4-foot vessel that was to be installed in loop D. The second new facility constructed was to obtain information on the problem of cooling the thermal shields. A 22½-inch sector of the thermal shield section of a full-scale reactor vessel having a 10½-foot inside diameter was constructed. The supension of glass

[1] Ed tor's Note.—Appendixes A through F on file in offices of Joint Committee on Atomic Energy.

beads were circulated through this sector at velocities comparable to those prepared in the design of the full-scale reactor vessel. As a result of these tests, it became apparent that the problem of adequately cooling these thermal shields was a much bigger problem than originally anticipated. Several methods have been proposed to overcome the difficulties indicated by this test program, but each requires a considerable amount of testing and some would add major complications to the plant system.

Gaseous recombination

In aqueous slurry fuel reactors, heavy water decomposes radiolytically into deuterium and oxygen, and must be recombined for both economic and safety reasons. This can be done either by a catalyst internal to the reactor system, or by catalyst beds, of existing design, external to the reactor system. In all of the early designs for PAR, internal recombination was preferred, but on the assumption that if a suitable catalyst was not found, an external system could be used. In the course of these design studies it was found that costly and complex auxiliary systems were required in order to prevent the accumulation of explosive mixtures of gases in the external recombiner. It was concluded, as a result, that a suitable internal catalyst must be found and thoroughly evaluated before the decision to proceed to a full-scale plant could be made.

During 1958, major equipment additions were made to our catalyst laboratories. These additions permitted screening of possible catalyst materials at almost double the previous rate. In addition, new special equipment was developed and put into use for long-term aging experiments to be carried out on the more promising materials found in the screening test. The Westinghouse Research Laboratory was brought in to assist on the overall catalyst problem. Early experiments indicated that silver would be a suitable catalyst for this reactor concept. During the past year, however, we found that when silver is mixed with the slurry fuel and the combination circulated at reactor temperatures and pressures, the silver is preferentially deposited on the walls of the circulating loop. No method of alleviating this problem had been found up to the time of the suspension of the project. The most promising material turned out to be palladium. It passed all preliminary tests, including circulation under reactor conditions of temperature and pressure, provided that an excess of hydrogen was added to the circulating loop system. At the time of the suspension of the project, samples of palladium were being irradiated at Oak Ridge under a cooperative program between Oak Ridge National Laboratory and PAR.

Effects of irradiation on slurry properties

It has always been recognized that much more information about the effect of irradiation on the properties of the slurry fuel and on any additives such as the catalyst would be needed before the decision to proceed with construction could be made. To obtain this information, the PAR project entered into a joint program with the Oak Ridge National Laboratory to carry out such work in the new Oak Ridge research (ORR) reactor. Appendix D shows the first PAR project in-pile test loop together with its auxiliary chambers and control instrumentation. This equipment was constructed during 1958 following the operation of a prototype unit discussed in some detail with your committee at the last hearings. The equipment shown in appendix D had been assembled at Pittsburgh and had been given a number of operating tests. ORNL personnel had come to Pittsburgh to be trained in the operation of the loop, and it was essentially ready to be crated and shipped to Oak Ridge National Laboratory in early 1959. This was to be followed by a series of similar test loops. This first test loop was originally scheduled for operation in the Oak Ridge research reactor in March of 1958, but due to many technical difficulties and other schedule delays, the first test loop could not be operated before some time in the second quarter of 1959. A joint ORNL–PAR program review made it clear that the amount of data which would have been available by the end of 1959 from this joint program, even with one or two test loops added, would not have been sufficient to supply the amount of information needed to make a technical decision on the overall problem. This in-pile test program review was initiated primarily as a result of the troubles which were encountered in the initial operation of the ERT.

Radioactive off-gas system

All of the reference designs prepared by the PAR project included a ventilation and gaseous waste disposal system which vented dilute activated gas and fission product gases through a stack directly to the atmosphere. Radioactive xenon was held up for a decay period of about three half lives, and provision was made to control gas release and to limit it to less than the permissible concentrations proposed by the Atomic Energy Commission. The ventilation and gaseous waste disposal system for reference design 2 was designed in this way. Engineering diagrams, components, functional specifications, and layout arrangements for the gas-handling and ventilation systems were prepared in enough detail that they could be used in the necessary reports required for an application to the AEC for a construction permit. Five possible plant sites were selected by the Pennsylvania Power & Light Co. for further study after an evaluation of more than 50 possible sites. As a result of such studies, it appeared that even though the concentration of radioactive gas discharged through the plant stack from a single reactor under normal operating conditions gave maximum ground-level concentrations of only 25 percent of permissible values, this would not be acceptable as a design basis in applying for a construction permit. Further study by the project along these same lines also pointed out the compounding of such problems if multiple plants or even a single very large plant was to be built at a particular site. Preliminary studies were therefore made of the technical problem involved in permanently storing the fission product gases. These studies indicated that such a procedure is feasible and is actually being installed at some existing AEC facilities. It meant, however, a complete redesign of this portion of the plant and the initiation of a new and enlarged development effort.

Remote maintenance

The problems associated with the maintenance of a fluid fuel reactor plant where direct maintenance of much of the system is out of the question have received major consideration from the inception of the project. A number of considerations led to the choice of an all-welded plant, one in which equipment requiring maintenance would be repaired in place by remote means or removed by remote means and repaired in an associated hot shop. To make this possible, a new family of remote maintenance equipment had to be developed and techniques for the operation finalized.

Major progress was made by the PAR project on the problem of developing equipment for making full-strength welds, by remote means, in stainless steel pipe ranging from 1-inch size to 20-inch size. An experimental model of a 10-inch automatic welding machine was adapted for remote operation. This machine has made completely acceptable full-strength welds. Appendix E shows a photograph of an experimental model of a welder-positioner for 1-inch piping. At the time of the suspension of the project, this machine was undergoing experimental tests and had already proved out the satisfactory design of the positioning equipment. Analogous devices for cutting, positioning and welding piping of other sizes were developed in complete detail to permit procuring such equipment in the immediate future. As a result of these design and experimental studies, the project was for the first time able to specify realistic linear and radial clearances for all piping layouts in order to permit the use of such remotely operated equipment. In addition, the project was able to specify for the first time whether such equipment could be used in any position or must be limited to a particular position. These considerations played a major role in the preparation of the detailed equipment and piping layouts to be discussed later.

In parallel with the development of the above equipment, an extensive experimental program was being carried out to determine the changes in design of particular pieces of equipment that would be necessary in order to permit such equipment to be remotely maintained. As a result of such a program, the design of a particular pump was modified so that the time required to remotely disassemble and reassemble it was decreased from 8 hours to 2 hours. While this result certainly was encouraging it also pointed out the magnitude of the development effort that would be required to incorporate the necessary features for remote maintenance into each and every component of the plant.

Plant layout

During 1958 a major effort was devoted to the preparation of a plant layout in enough detail that an overall plant cost estimate could be determined that would be accurate enough to be used in the overall decision with respect to

plant construction. The Stone & Webster Engineering Corp. continued to be the architect-engineer consultant for this type of work. During the earlier program, Stone & Webster had prepared plant layout drawings for reference designs 1 and 1–A. These plant studies consisted primarily of equipment layouts without detailed piping studies and were sufficiently accurate for the purposes required. It was determined, however, that the plant layout for reference design 2 should include not only equipment layouts but also detailed piping layouts, taking into consideration the results of the project studies with respect to remote maintenance. In addition, all auxiliary equipment such as the ventilation system, decontamination system, and building auxiliaries should be included.

Early in 1958, a senior Stone & Webster engineer was stationed at Pittsburgh in order to get first-hand experience will the problems and techniques of remote maintenance. He worked closely with the project engineers on the conceptual design of the overall plant and prepared the preliminary engineering sketches to be used as a basis for the final design. In July of 1958, he returned to the Stone & Webster offices in Boston to act as the lead man in the preparation of the final design drawings. Appendix F includes several typical drawings prepared by the Stone & Webster Corp. They are included here to show the detail that was included in the overall reference design 2 study.

As a result of the detailed piping layout studies, realistic compartment sizes were obtained for the first time. A basic difference evolved in the layout of plants for remote maintenance compared with the layout for a normal plant. For those compartments which have very large pieces of equipment, such as the reactor compartment containing the reactor vessel, main circulating pump and the steam generators, the basic size of the compartment is determined by the placing of the large components. When this is done it appears there is adequate room for all of the auxiliary piping needed for the interconnection of these pieces. In the case of the compartments which contain the more conventional equipment, such as small heat exchangers, drain tanks, and evaporators, the problem is quite different. In this case the size of the compartment containing such equipment is determined by the piping clearances made necessary by the requirements for remote maintenance. As a consequence, it was found that all of the compartments containing such equipment had to be enlarged considerably compared to those used in the earlier studies. As a result, the size of the vapor container increased from 175 feet in diameter to 190 feet in diameter.

Also included in these studies was the equipment for decontaminating any or all parts of the plant in case of an accident ranging in size from a small spill of the slurry fuel to the ultimate accident including the complete dispersal of the fuel throughout the vapor container. In attempting to specify the procedures and the equipment needed to place the plant into operation after such accidents it became clear that the basic information needed for such specifications was not available. It was determined that the extent to which radioactive contamination is spread throughout a plant when a component is removed from the system could only be found through the operation of a prototype reactor or its equivalent. Successful techniques for handling such matters have been developed in operating plants such as the HRT but at the expense of considerable down-time.

As discussed previously, the detail of the Stone &Webster plant drawings was to be sufficient for preparing a cost estimate of enough accuracy to be used in making the decision to proceed with construction. Such an estimate was to have been prepared by March of 1959 but was not carried out due to the suspension of the project.

SUMMARY

At the end of 1958, the status of the several major problem areas can be summarized as follows:

Gaseous recombination

Some possible catalyst materials showed promise but uncertainties about the effects of irradiation, corrosion products and long term hydrothermal treatment on the properties of these catalysts were great enough to preclude making a decision on the building of a full-scale plant.

Effects of irradiation on slurry properties

A program review made it clear that the amount of data available by the end of 1959 from the PAR–ORNL joint in-pile program even with one or two added test loops would not be sufficient.

Reactor vessel hydraulics

It became evident in mid-1958 that the problems of reactor vessel hydraulics and the cooling of the thermal shield would require high temperature testing that could not have been completed by the end of 1959.

Corrosion-erosion

The problem of erosion of materials in high velocity regions proved considerably more difficult than anticipated and resulted in essentially complete destruction of some pump components in only a few hundred hours. It would not have been possible to develop, design, and test replacement components in the time remaining in 1958 and 1959.

Plant layout and maintenance

The problem of maintenance and repair of defective components using completely remote methods has always been recognized as a major problem area. While significant progress was made by the PAR project on this problem, it became clear that the time the plant would be shutdown during such work was unknown. This and the other uncertainties indicated that the prescribed 80 percent plant availability factor could not reasonably be counted upon without first securing more knowledge of operating performance under actual operating conditions as well as experimental verification of proposed maintenance procedures.

Similar discussions can be given for many other areas. The overall status of the PAR project at the time of its suspension can be summarized by saying that as of the end of 1958 it had been established that (1) it was not technically feasible at that time to build a large-scale plant, and (2) this conclusion would not be altered by carrying out the program schedule for 1959. The objective of the PAR program from its inception had been to determine the feasibility of constructing a large-scale plant. It having been determined that such construction was not now technically feasible and that such feasibility could not be established in the near future, the program was accordingly suspended.

This outlook for the PAR project has obviously undergone considerable change as the research and development work has progressed from 1955 to date. It has been just this research and development which has produced the appraisal of cumulative facts and uncertainties described above.

It now appears that a very substantial amount of research work, including the construction and operation of a prototype, remains to be done before it can be established that it is technically feasible to build a large-scale single region aqueous homogenous reactor. All of the problems that face this reactor type are believed to be solvable with adequate time and effort, but there remains a basic question to be answered: What development pace should now be set for the homogeneous reactor within an overall nuclear power development program? Many elements are involved requiring most careful and thoughtful consideration because of the various changes in circumstances since mid-1955.

Chairman ANDERSON. Our next witness is Dr. Walter H. Zinn, Combustion Engineering Co. of New York.

Doctor Zinn, you know how welcome you are before the committee. We always appreciate your presence very much indeed.

STATEMENT OF WALTER H. ZINN, PRESIDENT OF GENERAL NUCLEAR ENGINEERING CORP., DUNEDIN, FLA., A SUBSIDIARY OF COMBUSTION ENGINEERING, INC., NEW YORK

Dr. ZINN. Thank you, Senator.

My name is Walter H. Zinn. I am president of General Nuclear Engineering Corp., Dunedin, Fla. Ten days ago, General Nuclear became a subsidiary company of Combustion Engineering, Inc., of New York. Today I speak for both companies.

Combustion Engineering and General Nuclear Engineering presently are engaged in a number of tasks directly related to the principal subject of these hearings, namely, the status of the commercial atomic energy industry.

Combustion Engineering is a major supplier of plant components for nuclear powerplants, especially pressure vessels for water-moderated reactors. The company is the prime contractor for a land-based prototype of a nuclear submarine which is under construction at its Windsor, Conn., facility. Cores for nuclear submarine powerplants also are manufactured at Windsor.

Specific reactor projects in which we are engaged include the following. In association with Stone & Webster Engineering Corp., a design study of an advanced type of large, pressurized-water reactor powerplant is being carried out for the Atomic Energy Commission. For the Puerto Rico Water Resources Authority, under an AEC contract, a comprehensive study and design is being made of the best means of adding nuclear superheat to a small boiling water reactor. Under contract to the U.S. Army, we are undertaking the operation and further development of a small, prototype boiling water reactor powerplant which recently was commissioned at the National Reactor Testing Station. For some time, we have been actively engaged in design, research, and development of a gas-cooled, heavy-water-moderated prototype reactor. This work is being done for the east central and Florida west coast nuclear groups of electric utility companies.

The objective of all of the above projects is the generation of electricity in a manner and at a cost acceptable to potential customers. A study also is being performed for the AEC of the best and cheapest way of producing large quantities of radioisotopes in a reactor.

I wish to comment briefly on only two of the aforementioned projects, namely the nuclear superheat study and gas-cooled reactor design.

The basic purpose of nuclear superheat is to raise the plant efficiency and thereby accomplish a reduction in the cost of power. If the superheat is to be added by the reactor, it means that steam becomes the coolant for the reactor. For a boiling water reactor, it means that water is boiled in part of the core and that the remaining part of the core is cooled by steam. We believe that there are several technically feasible schemes for doing this, but we also confess that the consequences to the performance of the machine are not easily apparent and it will take very considerable work to provide a well understood result.

It has been suggested that a simpler means of accomplishing the same end would be to boil water and produce steam in several reactors and to superheat this steam in a single all-steam-cooled reactor before sending the steam to the turbine. This scheme will have to wait for the construction of multiple reactor powerplants which, apparently, we are not quite ready to undertake.

In any case, we would like to point out that the techniques developed for steam cooling of a portion of a reactor core should be directly applicable to a completely steam-cooled reactor. Our studies of integral nuclear superheat are too preliminary at this time to state categorically that the improved efficiency obtained in the plant at the expense of some increase in complexity does, in fact, produce a lower power cost. We are optimistic that our studies will show this to be the case.

In association with the American Electric Power Service Corp., we have had almost a year of steady work on the gas-cooled reactor project. Two points in the design of the reactor concept have been verified by extensive calculation. With a gas outlet temperature of

the plant can be realized. An extrapolation from 80 electrical megawatts to 200 electrical megawatts can be made with somewhat greater assurance for the technical performance of the plant than for the economic performance.

It is a hard fact that only the actual detailed design and construction of a plant will yield the true cost and, further, during the years of operation, there may be reductions in the cost of the power produced, both due to improvements in the fuel cycle and to improved capacity of the plant. All that we ought to ask is that the nuclear powerplant be competitive in its cost over its lifetime.

I, as yet, do not see how it is possible by building and operating small prototypes or by the preliminary study and planning of large-scale reactors to solve this dilemma of the cost of nuclear power from large-scale stations without actually building and operating such stations. If we insist that all estimates and projections clearly show that nuclear power is fully competitive and that there is no financial risk to the operation before large-scale units are constructed, I fear that we may have to wait a considerable time, perhaps more than the 10 years stated as the goal of the program. It is my belief that the construction of large-scale plants should be undertaken if cost estimates show that the plant capital costs are within 20 or 30 percent of the competition and that the capital subsidy scheme also should be available for such projects.

In this case, the risk should be acceptable and there is always the possibility that some time actual costs will turn out to be less than the estimates.

The ad hoc committee report indicated that not all reactors which are studied or for which research and development is done should be carried through to construction. Some research is bound to yield unfavorable results and projects should be modified accordingly. I believe that such flexibility in the power demonstration program is a highly desirable feature. Currently, we have a number of examples where construction schedules are being postponed or abandoned because solutions to research problems are not forthcoming or the development of further information has shown that the economic projections of the reactor scheme are not as good as had been initially stated. Organizations will be loathe to undertake any projects with novel features if a decision to drop or modify the project when it fails to measure up cannot be made without incurring governmental or public criticism.

I am fully in agreement with the proposed policy of building and operating prototype power reactors within the framework of our conventional generating organizations, whether these be public or private utility companies. I believe it would be a serious mistake to set up nuclear powerplants and have their operation in the hands of contractors who, otherwise, are not in the electrical generating business. The capital subsidy proposal which has been made should make it possible for all generating prototypes to be integrated into existing utility networks and to be operated by utility company personnel and, in this way, make the surest progress toward integrating nuclear power with the power-generating industry.

The AEC program includes some effort on reactors for purposes other than the generation of electricity. The most obvious of these

1,050° F., it is possible to obtain steam conditions which are acceptable by modern steam practice and heat rates of 10,000 B.t.u./kw.h may be expected.

Secondly, a reactor system which is efficient in the utilization of neutrons is possible, and, in a large reactor fueled with natural uranium, permits burnups in excess of 4,000 MWD/T. This performance is predicated on the procurement of pressure tubes suitable for this application. Such tubes have been manufactured but are not yet tested. Design work on the reactor and on system components is proceeding and costs are being established. It is too early to make specific statements about the cost of power from this concept but, needless to say, this is one of the prime objectives of the work. Certain aspects of the technical feasibility of the design also are under vigorous investigation and, to this end, a number of experimental loops have been constructed and are being operated.

As in other reactor systems, corrosion is a vital topic and one in which questions can be resolved only by resort to tedious experiment. Our project has entered the phase where experimental results will determine the rate and extent of progress.

With your permission, I wish to comment briefly on the report produced by the AEC ad hoc advisory committee on reactor policies and programs.

I believe that in the statement of objectives and in the statement of reactor programs for obtaining the objectives the report has done much to clarify a difficult and complex subject.

The Atomic Energy Commission, in its statement at the opening of these hearings, has restated these objectives and has given the general framework for implementation of a program.

On the whole, I believe the program and the proposed implementation are sound and should be supported. I believe the goal of achieving competitive nuclear power in some areas of the United States within 10 years can be attained and that no basic investion is required to bring it about. While new reactor concepts which could make radical improvements would be welcome, there is little reason to believe that such major advances or breakthroughs are to be anticipated.

A base program of well-conceived research and development, plus design improvements, and the construction and operation of successive plants will bring improvements in all phases of the work and may very well succeed in improving the cost picture to the point where nuclear power can stand on its own.

The ad hoc committee report, in particular, did not point out any new reactor concepts which have been neglected. It would appear, therefore, that the primary job is to make improvements for the reactors already under investigation.

I believe there can be very little quarrel with the idea that there should be a vigorous program of construction of prototypes whenever a concept is judged to have progressed to a point where such construction is warranted.

Also, I am pleased to note that the size of what is called a prototype has increased to 80 electrical megawatts—not long ago we would have been inclined to call 80 electrical megawatts a full-scale plant. There is no doubt that in scaling the reactors from 80 electrical megawatts to perhaps 200 electrical megawatts further reduction in the cost of

that the plant capital costs are within 20 to 30 percent of the competition, and that the capital subsidy scheme also should be available for such projects.

I made the proposal some time ago that we might take the difference between a nuclear plant and a steam plant and perhaps subsidize 75 to 90 percent of that difference.

Are you alluding to something similar to that?

I am not trying to tie you to a dollar and cents program.

Dr. ZINN. Yes, I am alluding to your proposal. I believe it was restated by the Chairman of the Atomic Energy Commission when he made a statement here last week in somewhat different form. I mention it at this point to be sure that I make the point that I think this subsidy should apply to full-scale plants as well as prototypes.

Chairman ANDERSON. Are there any questions from members of the committee?

Mr. Holifield.

Representative HOLIFIELD. You are, in effect, advocating that we depart from our present formula of furnishing Government funds in the research and development field, and in the furnishing of certain materials on an advantageous basis, and you are advocating that now the Government step in and participate in the capital costs of these plants. That is in effect what you are advocating, Doctor Zinn?

Dr. ZINN. In effect it is, and I believe you can get as much ultimate good out of some dollars used in that way as you will in investing dollars in research and development. Do not misunderstand me. I am all in favor of research and development, but not all the dollars you spend in research and development do you any good. I think to arbitrarily say that one is good and the other one is bad is to be just that—arbitrary.

Representative HOLIFIELD. In setting 20 or 30 percent, you are not referring to 20 or 30 percent of the capital cost, but 20 or 30 percent of the end product, when the kilowatt cost is estimated to be within 20 or 30 percent? Is that what you are saying?

Dr. ZINN. That isn't what it says. It says plant capital cost and that is what I meant.

I would like to make a brief remark in that connection.

Fuel costs, I believe, for practically all reactors, can be improved during their lifetime and will be improved. It is bound to happen. So if you start out with a fuel cost of, let us say, four mills per kilowatt-hour, which is attainable now, I believe, over the lifetime of a plant, which is 20 years, this could very well be cut by 50 percent.

So I believe on the side of fuel costs the operating utility could take a little greater risk because they have the thing going in their favor. The more plants they build, the more certain it is that manufacturers will be able to lower their manufacturing costs. But the capital cost once made is there. It is in stone and brick and steel, and no improvement comes.

So I believe that the capital cost stumbling block is the harder one to get around.

Representative HOLIFIELD. I have one other point I wish you would comment on, and that is the importance of research and development in superheat transfer, and if there are any projects at this time planned which would advance this particular area.

is industrial process heat. The main difficulty with a reactor for process heat lies in the fact that the ordinary process heat source is small by nuclear reactor standards which, therefore, seriously penalizes the cost of heat from the reactor. Nevertheless, if we are concerned with the long-range fuel resources of the country, we should give attention to the fact that electricity generation probably never will account for more than 20 percent of the total energy used. It would appear to be appropriate to give some concrete recognition to the need for other uses, such as process heat, and to obtain some pilot plant experience. I am pleased to see that the Commission program specifically includes steps in this direction.

I believe the discussion in the last several years of the civilian reactor program has served to develop some clear-cut objectives and the beginning of a specific program which can lead to achieving the objectives. The task is not an easy one, and it will take hard work and realism by all parts of the nuclear industry to make the progress the Congress and the public have a right to expect.

I want to express my appreciation and thanks for again having the privilege of making a statement before the committee.

Chairman ANDERSON. I know you know, Doctor, that the committee has been very much interested in this problem of process heat also. We are very glad to have your comments about it.

On page 5 I have marked something about—

> All that we ought to ask is that the nuclear powerplant be competitive in its cost over its lifetime. I, as yet, do not see how it is possible by building and operating small prototypes or by the preliminary study and planning of large-scale stations without actually building and operating such stations.

Do you think that the building and operating of the Shippingport plant has been very useful in giving us a lot of answers that we might not have had if it had not been built?

Dr. ZINN. Yes, sir.

Chairman ANDERSON. I do, too, and I am glad to hear you say so. Do you think that that could follow over into other plants as well, then, that by building them we might learn some things that we otherwise would postpone learning for a good many years?

Dr. ZINN. I believe that inherently the nuclear power business is a large-scale facility business. I think that is inherent in the nuclear reactor.

I do not believe you can learn everything by operating a small-scale prototype. I also believe we have good examples in our own country of the economy that comes with a large-scale operation.

Earlier today I believe Mr. McCune mentioned the diffusion process for separating uranium 235. Some people believe that the price of uranium 235 is phenomenal; that it is low. I believe this is due, to a great extent, to the large-scale operation. Similar statements, probably, can be made about our plutonium production.

Of course, we do have examples in other countries where large-scale power reactor experience is being obtained. I do not think the U.S. program should go on many years without also getting large-scale experience. I recognize the difficult financial problem, I recognize it fully.

Chairman ANDERSON. You say a little farther down that construction of large-scale plants should be undertaken if cost estimates show

Dr. ZINN. Well, I think the ad hoc committee report made it very clear that what we have to do is improve the reactor concepts we have now, and stop looking around for new ones which are much better. In looking at the water reactor, it is quite clear that one of its deficiencies is that it produces, ordinarily, saturated steam at a rather low temperature and, therefore, all of the generating equipment is old-fashioned in one sense, but has required rather new development to make it satisfactory.

If, without too much complexity, you could manage to superheat the steam in the reactor, you presumably make an improvement, and it is improvements we are looking for.

Representative HOLIFIELD. Would you say that that superheat should be nuclear or conventional superheat?

Dr. ZINN. Well, I am in the nuclear business. I believe we should make it nuclear. I do not think the idea of adding an oil burning superheater is any more than a stopgap.

Representative HOLIFIELD. Of course that is being done, I believe, at the Consolidated Edison plant.

Dr. ZINN. Yes, at the Consolidated Edison plant and, of course, if you want an example, I believe the Russians are building a reactor in which they have nuclear superheat.

Representative HOLIFIELD. If we get on to this project out in Idaho, I think it might be possible that we would develop along this line, develop the capacity to do this job.

Dr. ZINN. Well, we believe that it is feasible technically to do it in either the boiling water, which is a small reactor to do it in, or perhaps a pressurized water reactor. There are, I think, three projects under AEC cognizance to do this. They are going on at the present time. They have been started in the past 3 or 4 months.

Representative HOLIFIELD. You know, of course, that the Puerto Rican concept has not been approved in the Commission's submission of an authorization bill draft.

Dr. ZINN. I missed it.

Representative HOLIFIELD. You did?

Dr. ZINN. Yes.

Representative HOSMER. Doctor, I take it that you are a little less enthusiastic about the immediate prospect of immediate superheating than you were when you testified last year.

Dr. ZINN. No. I believe the contrary is true. Our people have had only a couple of months of intensive work on it, but they report to me that the technical side of it looks all right, looks feasible. It is a little harder to get at the economic effect. Of course, success depends on showing that overall you reduce the cost of power. You may raise the efficiency of your plant, but that does not mean you reduce the cost of power if you had to add capital costs and fuel costs, which cancel out your gain.

Representative HOSMER. I notice that you strongly suggest the intensive development of present types. I wonder whether you consider the General Dynamics proposal in the present type category or something beyond?

Dr. ZINN. I consider gas-cooled reactors present type. I don't think you can call them anything else because there are too many around. I also believe the higher the exit temperature of the gas, the better

off you are. There is no question about that. On the next point as to whether or not one can operate a plant in which the pressurized gas is also highly radioactive, I have some doubts. I think here is where I would differ with the General Dynamics proposal. I believe that one of the limitations that we must face is to stay with temperatures that enable us to contain the fission gases in the fuel.

The next step is to go to higher temperatures where you know you can't contain them. It might be successful. I just don't know.

Representative HOSMER. I notice that you are talking enthusiastically in the increase in size of the prototype plants. Do you think this General Dynamics thing is for 35,000?

Dr. ZINN. I believe——

Representative HOSMER. Would that fall well within the prototype range?

Dr. ZINN. I believe one should not connect the word prototype with size. A prototype ought to be designed so that it leaves no major question unsettled in moving to the large reactor. For different reactor concepts, the prototype will have different sizes. For instance, I can't see much reason in bringing a light-water moderated reactor over 20 or 30 electrical megawatts as a prototype.

Representative HOSMER. I am glad you brought that out. There has been some confusion in thinking that once you get up to a particular size you are big, and if you don't get there, you are small. But it depends on what you are dealing with.

Dr. ZINN. Eighty electrical megawatts, of course, is a pretty large plant. If you want to call it a prototype, it is all right with me. I merely point out that not long ago we were thinking of 60 electrical megawatts as a full-scale powerplant.

Representative HOSMER. You have endorsed the idea of building certain water plants. We have the pressurized water plant on that basis and the BWR is coming along at Dresden. What other candidates would you suggest as likely candidates?

Dr. ZINN. For the American program, you have to take it in steps. I believe that the pressurized water and the boiling-water reactors should not stop with the ones now under construction. I don't also say that one should immediately start building further models without getting some experience. But to stop there with our first sizable plants might be a fairly serious error. We might miss that last improvement which would give us economic power.

The next types of reactors that will be ready for that sort of development in this country, I believe, will be gas-cooled reactors, if they ever become ready. They will be the next ones. The prototypes have not been built.

Representative HOSMER. Of natural uranium or of the enriched variety?

Dr. ZINN. I don't think it makes too much difference in our country. I believe that the reactors are better ones if they use very low enrichment. Let me put it another way. I think they are better reactors if the neutron economy is good, which usually means low enrichment or natural uranium reactors.

I also believe that where enriched uranium is readily available, you may improve the performance of almost any reactor by using some enrichment. I believe I said that last year in my testimony.

Representative HOSMER. What would be your opinion of a program under which all prototype reactors were built on Government sites at Government expense without industrial participation?

Dr. ZINN. I think it would be an error. I would like to have the opportunity of saying why. I think if that program were adopted that inevitably these reactors would be operated by companies, contractors, and by people, who ordinarily would not be in the electric generating business. After all, if this technology is going to be useful, it ought to be used by the people who have that business now. Nuclear energy for many years is only going to be a small increment, a small addition to the electric generating business. I think that one of our responsibilities and jobs is to get it into that same framework so it won't always be an odd ball, if I may use an expression.

Representative HOSMER. When we take one of these things, we not only learn the nuts-and-bolts side of it but the paper-shuffling side of it at the same time; that is your theory?

Dr. ZINN. A lot of things which I am afraid laboratories and Government contractors, perhaps, do not have to deal with, but utility companies do.

Representative HOSMER. Thank you, Doctor.

Chairman ANDERSON. On the question about building all of these prototypes at Government sites, you were on the staff report, but that was not what it recommended, was it, or it isn't what the Joint Committee recommended?

Dr. ZINN. That is right.

Chairman ANDERSON. They might build the experimental models, but when you got the others——

Dr. ZINN. I think reactor experiments might very well be built there, because reactor experiments do not even have to generate electricity.

Their purpose is to try out an idea. But a prototype is a generating machine. It makes electricity and useful electricity. If it is 80 electrical megawatts, it is worth having and distributing.

Chairman ANDERSON. Some of them are kind of in between, are they not, like the Kaiser ACF?

Dr. ZINN. Well, I do not know about that one. If some utility company wanted that particular reactor, I would see no objection to putting it at a site provided.

Chairman ANDERSON. Neither would I. We put it up for grabs and nobody wanted it.

Dr. ZINN. Then it ought to find shelter somewhere else.

Representative HOLIFIELD. I just wanted to clear up the question of industrial participation.

It is my understanding that regardless of where a reactor is built or who builds it or who pays for it, industry has to do the job of participating in the building of it. If the meaning is for utility participation, I agree that the Atomic Energy Commission should not operate a utility plant. I would certainly be the first to agree to that. However, in every case I know of, whether it is Oak Ridge or the TVA, or where the OVEC combine to furnish electricity, or Hanford, where it is obtained from the Columbia network, there are utility companies furnishing electricity to atomic energy sites.

It would be, of course, very easy to contain, whether it is the case of TVA or others, for the utility to participate to get the experience out of it, along with the industrial manufacturer of the component parts.

So on that basis, I would say that I would agree with you, that industrial and utility participation would be desirable if available, at all places.

Chairman ANDERSON. Mr. Van Zandt.

Representative VAN ZANDT. Doctor, on page 4 of your statement, you refer to the program that was submitted to the committee by the Atomic Energy Commission.

No doubt you have in mind the five-point program that was presented to the committee by Chairman McCone?

Dr. ZINN. Yes. I only have a news release on it, so I don't know whether I have it complete. But I think it had five points in it.

Representative VAN ZANDT. You also state on page 4 that:

> I believe the goal of achieving competitive nuclear power in some areas of the United States within 10 years can be attained and that no basic invention is required to bring it about.

In other words, you are willing to lean on the present concepts of reactors and improvements, and from these improved reactors you think economic competitive power is possible of developments?

Dr. ZINN. I think, Mr. Van Zandt, that we have had something like 15 years of exploring the subject and trying to find new embodiments, as one of my colleagues frequently calls them. I think by now we pretty well understand most of the possibilities, and that most of these are under investigation, or all of them are under investigation someplace in this country.

We are not really pressed for a new idea. We have some pretty good ideas.

I think it is time for us to bear down on some of them and improve them. You can't do this, unfortunately, without successive construction.

Representative VAN ZANDT. In recognition of your many years of association with the Commission, and the vast knowledge you have in the atomic field—especially reactor development—I would like to read a statement made by the Chairman of the Commission to the committee, he said this:

> It shall be the responsibility of the Atomic Energy Commission to provide positive and vigorous leadership in the national efforts to achieve these goals.

Doctor, let me ask this question of you: Are you satisfied that the efforts of the Commission at the present time are adequate to achieve the goals mentioned?

Dr. ZINN. I believe that if the Commission carries through vigorously with the programs it now has in hand, and they are pretty extensive, and if they have the funds to back them up, that this is a good example of leadership.

Representative VAN ZANDT. Then it is a two-way effort here. First the Commission has to implement the program; and, second, the Congress has to provide the money to implement it.

Dr. ZINN. That is a sad fact, but without money we do not do anything.

Representative VAN ZANDT. Do you believe the Kaiser ACF gas-cooled design should be a power reactor or a flexible testing reactor?

Dr. ZINN. I do not believe it is necessary to generate power to learn most of the things that you have to learn about a gas-cooled reactor system. The gas-cooled reactor system in particular uses large heat exchangers and raises steam in them. These must be tested. But the steam does not have to go to a turbine in order to know what you are doing.

So the requirement that it generate power is not basic to the system. I would also make the statement that if it is not part of a utility network, I do not see much point in making the power. I think the power turns out to be sort of a liability. You have to get rid of it somehow, and you are not in good shape to do it.

Representative VAN ZANDT. Do I understand your answer to my question is that it should be a flexible testing reactor?

Mr. ZINN. I believe that the proposal as I now understand it is going to require being flexible because the proposal calls for building and operating a system at temperatures well over 1,000° F., using helium gas as a coolant. This is a hard job. I do not think one should count on it immediately going into operation and having a fine history of operating up to expectations right away.

I think it is a hard thing to do. The higher temperature and the fact that it is helium, which is hard to contain, will make it quite a difficult operation.

Representative VAN ZANDT. That is all.

Mr. RAMEY. When you spoke of existing technology, in 1956, I guess, you mentioned five types of reactors that might be concepts that could be utilized in an expanded program. As I recall, you mentioned heavy water cooled and moderated reactors as one type of technology that should be gone into in the prototype stage, taking off from the Savannah River technology. Do you think that is still an existing type?

Dr. ZINN. Yes. And actually I believe there are four projects in the United States associated with that general idea. There is a test reactor at Hanford, there is a component test one at Savannah River. There is the Virginia-Carolina Utility Group project, and the East Central Nuclear Florida and West Coast Nuclear projects.

Mr. RAMEY. But none of them are operable with natural uranium.

Dr. ZINN. Even 2 years ago I would not have said that a heavy water reactor of prototype size would be operable with natural uranium. That can only be done with a large reactor, just because of the neutron leakage to the outside. But we understand that very well. If we get a prototype operating, even if it is on enriched uranium, and we understand the system, we can know how it will behave on natural uranium if it is large.

Mr. RAMEY. Do you consider an organic type of reactor as being another type that we have sufficient knowledge of now and can go ahead on?

Dr. ZINN. I would defer there to the ad hoc committee which, if my memory serves me right, said that a real prototype should now be built.

I do not know whether they said what size. But the ad hoc committee definitely recommended that a prototype, organic moderated machine be built promptly.

Chairman ANDERSON. Mr. Price?

Representative PRICE. Dr. Zinn, do you feel, or do you feel that in the present power administration program we are exploring every promising type of reactor that you can think of?

Dr. ZINN. Well, again, I would not want to substitute my judgment for a group of men who have just gone through it.

Representative PRICE. I am asking for your personal judgment. I will not weigh it against their judgment. Can you think of any type of reactor that you think would be well to explore which is not now in the program?

Dr. ZINN. Perhaps on a very experimental basis there are some which would lead to higher temperature. For instance, as far as I know, nowhere in our program is anyone seriously doing anything about berylium as a moderator. I do not think it is a matter of consequence because of the scarcity of berylium. Still, it does have some interesting properties.

I do not know that our program has in it enough emphasis on using liquid metals in a special way, namely with quite high temperature. I believe there is enough effort on liquid metal cooled reactors at around 1,000° F. But it is possible to think of liquid metal cooled reactors up to higher temperatures, 1,400° or 1,500° F., and I am not sure there is enough effort along those lines. But here again you have to make choices somewhere. You cannot support everything.

Representative PRICE. I am not asking this for the purpose of argument, but just in exploration of the different types of reactors that possibly should be considered, particularly when they are still in the research and development stage.

Dr. ZINN. By and large I would say that our program is extensive and inclusive. Not much is being left out.

Chairman ANDERSON. Are there any other questions?

If not, thank you very much, Doctor.

The next witness will be Mr. Palmer.

STATEMENT OF ROBERT S. PALMER, NATIONAL WESTERN MINING CONFERENCE, DENVER, COLO.

Mr. PALMER. Chairman Anderson and members of the committee, my name is Robert S. Palmer. I am from Denver, Colo.

The National Western Mining Conference recently held in Denver, attended by a substantial majority of the domestic uranium miners and a representative group of the end users of the products of uranium, expressed a sincere appreciation for the attention given and consideration shown to the problems of the domestic uranium industry by the members of the Joint Committee on Atomic Energy of the Congress and requested me to express our thanks to you and our confidence in the Committee's and the Atomic Energy Commission's ability to protect the best interests of the United States and the domestic uranium mining industry.

The members of the committee are fully advised as to the importance of a continuing and healthy uranium industry to the present economy, as well as the future welfare, safety, and security of the Nation.

The more than 2,000 mining operators at our conference were impressed with the information released by the Subcommittee on Raw

Materials and by spokesmen for the Division of Raw Materials, later supplemented by a declassified version of the AEC statement of February 16, 1959, issued February 24, 1959. We appreciate the alleviation of misinformation used by some to send up distress signals. The industry is comparatively new and needs the assurance of continuity.

Many problems confronting the domestic mining and milling business were discussed at our conference by leading representatives of the industry with Members of Congress and representatives of the Commission which helped to clear the outlook for future stability. In fact, we hold these conferences each year for that purpose. After all views were recorded, the official resolution of the conference was adopted as follows:

URANIUM

We commend the Commission for granting additional domestic uranium concentrate milling facilities as announced by its April 2, 1958, press release. We recognize that the AEC is keeping faith with the domestic industry it has sponsored in granting additional milling facilities to the relief of domestic industry.

We urge the AEC not to grant additional leases on withdrawn lands for production of uranium ores which would compete with private producers. We agree that the AEC should continue with existing leases to enable lessees to recoup investments and recover reasonable profits.

We urge the Commission to keep any system of production allocations flexible enough to permit practical operation of our domestic uranium mines with a minimum of economic dislocation and inequity.

We do not advocate cancellation of foreign agreements; we strongly recommend that the AEC make no more foreign contracts or extensions of existing contracts.

We urge the AEC make available to private industry estimates of future requirements of uranium oxide. We realize that military requirements may be classified information, yet the Commission can accurately predict and make available to us, with safety, the combination of both military and civilian requirements.

We commend the Atomic Energy Commission for its work in the field of scientific research and development. We urge that the Commission continue to further research that will promote the development of industrial uses for uranium.

I am sure the chairman of the committee has been advised that the New Mexico Association has subscribed in substance to this resolution and also the Wyoming Mining Association.

Thereafter, assurances were given by spokesmen for the Atomic Energy Commission that no official action had been taken by any governmental agency, nor was one contemplated for the near future designated to renegotiate or extend contracts or commitments to purchase uranium from foreign sources which expire in 1963 or 1963.

Mention was made of a printed pamphlet sent out by a uranium producers' committee of an association similar to ours, outside the boundaries of the United States; but assurances were given by Members of Congress attending the Denver conference, as well as spokesmen for the Commission, that the pamphlet had not resulted in inspiring any official representations to the Government of the United States, or any division thereof, regarding the extension or renewal of existing contracts for the purchase of uranium from outside sources by the particular government in question.

The AEC has entered discussions with the domestic industry concerning the possibility of "stretching out" to a greater period of time the uranium procurement program or limiting domestic production in

an effort to reduce the Government's procurement allocations over the next 3 fiscal years.

Assurances were given that in the event additional limitations are placed upon production within the United States that these limitations will not affect the hundreds of small independent uranium operators who have in many instances invested their entire life savings in their individual operations and are largely dependent upon the income derived therefrom.

We believe the members of the committee share our views that every effort should be expended within the limits of our financial ability to continue in the United States an active, healthy, domestic uranium industry; that it would be a serious mistake to cripple the economy of the primary areas affected from uranium production by the adoption of policies which have been so destructive to other segments of the mining industry.

No industry has experienced faster changes than the uranium industry and there are sound reasons to assume that rapid changes in consumption and demands for our products will take place during the next few years. We are not prone to yell "wolf" unless we have some accurate knowledge that the wolf may appear; nor are we inclined to subject the industry to cold chills by emphasizing the dangers which confront its essentiality to our Nation's future well-being; nor are we convinced that the disparity between prices paid for production of domestic uranium and those currently paid for some outside production will not be equitable adjusted at the proper time or perhaps discontinued if the Nation's and the domestic industry's requirements warrant such action.

The stockpiling of our product is and will continue to be in the national interest rather than a program which would result in the stagnation or possible destruction of large investments in capital expenditures. Experience teaches that mining operations must be based on a continuing program and that closedowns are costly not only to those primarily involved but to the Nation's economy as well.

Surely no such destructive programs will be approved or sanctioned by this committee without full and complete hearings being had and the subject matter carefully appraised.

We wish to assure the members of the committee of our continued confidence in your sound judgment and that, should it develop that the market for uranium for civilian purposes, as distinct from military uses, be small in relation to the productive capacities of the mines, that the domestic uranium industry will be fully protected by the adoption of stockpiling, programs or other policies designed to insure a continued, active, healthy, domestic uranium industry.

We again wish to express our appreciation for the consideration we have been given and are being given by the Atomic Energy Commission, its efficient staff and field representatives. No reliable evidence indicates that there are any secret negotiations behind closed doors being conducted which threaten our future. We must rely on our Government to safeguard our interests.

We have every reason to believe that through the cooperation of the Joint Committee and the Atomic Energy Commission Raw Materials Division we will receive the consideration which will insure the future of our industry.

Thank you.

Chairman ANDERSON. Are there any questions?

If not, thank you very much.

The next witness will be Mr. Elmer L. Lindseth.

STATEMENT OF ELMER L. LINDSETH, PRESIDENT, CLEVELAND ELECTRIC ILLUMINATING CO.; AND CHAIRMAN, EDISON ELECTRIC INSTITUTE COMMITTEE ON ATOMIC POWER

Mr. LINDSETH. My name is Elmer L. Lindseth. I am president of the Cleveland Electric Illuminating Co. and chairman of the Edison Electric Institute committee on atomic power.

The institute represents 193 operating companies serving 97.6 percent of all customers of the investor-owned segment of the utility industry. These customers comprise 75 percent of our Nation's electric users.

It is in behalf of these investor-owned companies and their customers that I am testifying here today. This statement has been authorized by the institute's committee on atomic power, the makeup of which is attached.

INVESTOR-OWNED UTILITY PROGRAM

The Nation's electric utility companies are today actively engaged in a broad industry program for the development of economically competitive nuclear power.

Three nuclear power projects in which electric utilities are participants are in operation; seven utility-sponsored projects are under construction or contract; and five are in various stages of planning or negotiation with the Atomic Energy Commission. The 10 projects that are either in operation, under construction or under contract will involve utility company expenditures of some $375 million.

The five projects in various stages of planning or negotiation are expected to involve further utility company investments in excess of $165 million. In total, these 15 nuclear power projects involve utility expenditures of over $540 million.

Utilities are also participating in 11 other nuclear research, development, and study projects involving substantial expenditures. Some of these will undoubtedly lead to additional reactor construction projects. As of the end of 1958, utilities have spent in these and the previously mentioned nuclear power projects approximately $130 million. In all, 131 utilities are participating in these programs. These companies and the various utility projects are listed in appendix I.

PROGRESS DURING PAST YEAR ON UTILITY PROGRAM

During the last year, there has been further expansion of the electric power companies' program, continuing progress on nuclear projects already underway, and cancellation of one project.

A firm proposal was made to the AEC by the Philadelphia Electric Co. and the High Temperature Reactor Development Associates to design, construct, and operate a 30,000–40,000 kilowatt (electrical), high-temperature, helium-cooled, graphite-moderated nuclear power-

plant. Last week AEC reported that the HTRDA project has been accepted as a basis for negotiations.

General Public Utilities Corp. announced in January 1959 that it had reached a basis of agreement with Westinghouse Electric Corp. for the construction of a 5,000 kilowatt (electrical), developmental water-type reactor at the Saxton, Pa., generating station of its subsidiary, Pennsylvania Electric Co.

In December 1958, Pennsylvania Power & Light Co. and Westinghouse Electric Corp. advised the AEC that after 3 years of research and development work on the single-region, slurry, homogeneous reactor, they did not think it technically feasible to construct a large-scale homogeneous reactor without the development and operation of a prototype plant. This resulted in the cancellation of the project (PAR).

During the year a contract was signed between the Carolinas Virginia Nuclear Power Associates and the AEC for the construction of a 17,000-kilowatt plant at Parr, S.C.

The East Central Nuclear Group-Florida West Coast Nuclear Group project was authorized as part of the third round of the power demonstration reactor program on August 4, 1958, and a contract has been negotiated with the AEC.

Negotiations are underway between the AEC and the Northern States Power Co. for research and development support for a nuclear superheater to be incorporated in the 66,000-kilowatt (electrical) plant to be located at Sioux Falls, S. Dak.

Major construction work on the large-scale Dresden, Enrico Fermi, Yankee, and Indian Point atomic electric plants proceeded toward completion and operation in 1960 in the case of the first three plants and 1961 for Indian Point.

Valuable experience was obtained by the electric utilities particpating in the three operating power reactor projects—Vallecitos, Santa Susana, and Shippingport.

Many other companies continued their participation in a wide range of research and study projects in the field of nuclear power development.

Details on all projects and a listing of the participating companies are shown in the appendixes.

THE FUTURE

The future course of civilian nuclear power development in the United States is of vital importance to the Nation's electric utility industry and its customers.

Hence, the members of the Edison Electric Institute concur that the Nation's policy objectives should be clarified in this area, and that the respective roles of Government and industry in the achievement of these objectives be delineated.

This statement has been prepared in an effort to help clarify the national objectives in the development of nuclear power and set forth certain principles to which we believe the Nation should adhere in the achievement of these objectives.

Suggested national policy objectives in nuclear power development

There appears to be wide agreement that one of the major objectives of any national program should be to fortify the country's position

of world leadership in the peaceful applications of atomic energy, particularly with regard to electric power generation, a position which America has long held in the field of conventional power.

A second major objective, essential to the attainment of the first, is to achieve and demonstrate economically competitive nuclear power at the earliest practical date in the United States and in high-fuel-cost nations of the free world. This will achieve a third major objective, namely, to assure the continued availability of an abundant, relatively low-cost energy supply to supplement the Nation's fossil fuel resources at such time in the future as it may be required.

We concur in these objectives.

A fourth objective, which we believe has not received adequate consideration, is to bring the development of atomic power as soon as possible and as nearly as possible within the framework of commercial development of conventional energy resources. Healthy, ultimate utiliaztion of atomic energy will only take place with electric power companies, manufacturers of equipment, and other interested industries working together, without the requirements of special restrictions, special forms of assistance, and the extent of direction by Government which presently exist during the transition period to economic nuclear power.

The inclusion of this objective in our national program would help carry out the principle set forth in section 1 of the Atomic Energy Act of 1954, namely, to maximize participation in and ownership of facilities by private enterprise and thereby assure that normal business incentives and the Nation's normal business system will at the earliest practical date replace Government control, direction, and ownership.

In setting forth the objectives of any national program, the industry believes that inasmuch as the outlook for costs of power from conventional fuel varies and will continue to vary widely among geographic areas, and from time to time, too great emphasis should not be attached to specific target dates for the achievement of competitive nuclear power either within the United States or abroad.

Rather, emphasis might be placed on carrying forward a vigorous and orderly program of nuclear power research, development, and construction consistent with unfolding technological developments. Such a program can be aimed at achieving competitive nuclear power in the United States and abroad through the expenditure of such amounts of money, time, resources, and manpower as are consistent with the attainment of the objectives set forth above and in the light of conditions prevailing from time to time and technical progress.

Responsibility for domestic power supply

The Nation's electric power companies have the responsibility to insure domestically the availability of an abundant supply of low-cost electrictiy. Their success in meeting this responsibility in the past is a matter of record, and every indication points to continuing success in meeting this responsibility in the future. One part of this responsibility involves a vigorous program for the development of economically competitive nuclear power. The program for nuclear power development in the United States to which electric power companies have been and are making a major contribution has been pro-

gressing at a rate which is both substantial and adequate on the basis of domestic considerations.

Meeting international objectives is multiple responsibility

The objectives of the electric utility industry are entirely congruent with those of national policy. However, the achievement of the Nation's foreign policy objectives in the field of nuclear power may require efforts that exceed those indicated by domestic considerations. Such additional efforts are a collective responsibility of all segments of the economy. The electric power companies recognize their responsibility in these efforts and will continue to make available to the fullest extent possible their resources in experience, organization, and financial support to help achieve the Nation's foreign policy objectives in this area.

Long-range program of nuclear power development

The electric power companies also endorse the principle of the Nation's setting forth a long-range nuclear power development program to achieve its policy objectives. Such a program, covering a period of perhaps 10 years into the future, should, however, have built-in flexibility, both in technical decision-making and in administration, and should include only general technical objectives and desirable reactor concepts. Rigidity resulting from too detailed a listing of technical problems and reactor concepts should be avoided. Such a listing takes on the appearance of finality which is likely to impede adequate exploitation of new developments.

Program flexibility requires that the steps proposed to achieve long-range objectives be formulated only in provisional terms, with definiteness for 2 or 3 years forward. Moreover, provision should be made for periodic examination of the program by the AEC and any other authorized agency or group to foster developments consistent with new technical achievements.

To insure broad latitude in the approach to established objectives, efforts should not be limited solely to the carrying out of any single proposed program that may be adopted. Adequate provisions should be made for individual decisions and actions on projects outside the framework of such a program. Unsolicited projects proposed by industry for new reactor concepts should be invited and encouraged. Basic decisions such as the selection of promising reactor types should be fostered by as many independent groups as possible, including the AEC, manufacturers, individual utilities or groups of companies. Emphasis should be given to reactor experiments and prototype reactors rather than large-scale power reactors.

Not all of the reactor research and development projects undertaken should be expected to be carried to the construction stage. In cases where research and design studies do not show sufficient technical and economic potential, construction should be postponed or canceled.

Role of Government in nuclear power development

During the transition period to competitive nuclear power, the Atomic Energy Commission will have an important part to play in virtually all aspects of reactor development. However, that role should be a transitional one with such responsibility transferred to

industry as soon as practicable in order that nuclear power may truly develop in keeping with section 1 of the Atomic Energy Act of 1954, namely, that "* * * the development, use, and control of atomic energy shall be directed so as to * * * strengthen free competition in private industry."

The AEC's role in reactor development over the near term should be in the areas of investigating promising reactor concepts, sponsoring research and development, and constructing and operating reactor experiments and prototype reactors. AEC ownership should not extend beyond the stage of such reactor experiments or prototype at Commission installations. Moreover, such reactors should be operated only so long as they are deemed to be valuable from a research and development standpoint. In many cases, the inclusion of electric generating facilities is not necessary for technical progress. In those cases where generating facilities are installed, power generated should be utilized at the site.

Maximum participation by industry in program

The respective roles of Government and industry in carrying out any program deemed necessary to meet the objectives should be so conceived and administered as to maximize participation in the ownership of facilities by industry.

Hence, projects proposed by the AEC involving either prototype or subsequent reactors should be submitted to industry to be constructed, owned, and operated by industry, and sufficient financial assistance should be provided to bring this about.

The willingness or lack of it on the part of industry, given financial assistance, to undertake the construction, ownership, and operation of a particular reactor should itself be recognized as a significant test of that reactor's competitive promise.

Electric power companies, in order to further the development of nuclear power, have consistently been willing to invest in atomic powerplants amounts greater than the equivalent cost of conventional plants, as well as substantial amounts for research and development, and may be expected to do so in the future.

Government assistance to industry

Broad-scale industry participation in expanded programs to meet the Nation's foreign policy objectives will require substantial participation, both financial and otherwise, by the Federal Government. Such assistance is both desirable and necessary, inasmuch as it is in support of an objective important to the entire Nation rather than for the benefit of any one group. The principle of Federal financial aid to promote international objectives has abundant precedent for such a Federal role in nuclear power development.

Such Federal assistance must be flexible enough to encourage research and development of all promising reactor types and should not be limited to specific types of assistance which might tend to warp the technology. The forms of assistance should be broad enough to encourage and obtain the maximum amount of industry participation.

Financial assistance should also be made available by the AEC for promising research and development projects without necessarily requiring that those undertaking the project or research work commit themselves to ultimately building a reactor. The requirement

of coupling aid for worthwhile research and development to a commitment to build a plan is unsound and uneconomic, respecially when investigations indicate that a plant subsequently should not be built.

The participation of the electric power industry in individual projects will assure that the cost-cutting incentives of industry will result in progress at least cost to the Government.

Attracting industry participation

Industry sponsorship should be encouraged for all power reactor construction projects, whether proposed by the AEC, authorized by the Congress, or unsolicited.

Projects proposed by the AEC might specify in broad terms the type, size, and other characteristics of a desirable project with ample time provided for both preparation and evaluation of proposals.

The industry group submitting the most favorable proposal to the Government, giving effect to the amount and type of Government assistance, should be assigned sponsorship for the project. Government financial assistance might be paid either by direct contract between the AEC and the manufacturer or to the building utility.

Unsolicited proposals from industry should similarly be encouraged and invited.

To date, electric power companies have invested in nuclear power projects amounts substantially in excess of the equivalent costs of conventional plants for both AEC proposed and unsolicited proposals, thus reducing the required expenditure of Government funds.

Discrimination and preference

As we have testified in previous years, to provide a nondiscriminatory means for disposal of any electric energy that may be generated by Government-owned experimental nuclear-power facilities, section 44 of the Atomic Energy Act of 1954 should be amended.

Also, the preference clause in section 182 which provides for preferred consideration of license applications by public or cooperative bodies should be deleted.

Preservation of U.S. normal business system

Finally, as this new field of energy unfolds in the United States, it is particularly important that at each stage of development prime consideration be given to the maintenance of the normal business system which has given the United States world leadership in the power-generation field. Whatever the Nation has in the way of productive capacity can be credited to that system; every effort should be made to protect and strengthen it.

We believe that the adoption of these principles to guide the U.S. course of action will result in achieving the Nation's objectives both at home and abroad on time and at minimum cost to the Nation.

I would also like to have filed with the record the five appendixes attached to this statement which are a material part of it, and to express our appreciation for this opportunity to appear before your committee.

Senator BENNETT (presiding). Mr. Lindseth, the material you have added to your statement will be accepted and included in the record.

(The material referred to follows:)

APPENDIX I

(Status as of Feb. 15, 1959)

ELECTRIC UTILITY COMPANY PARTICIPATION IN NUCLEAR POWER DEVELOPMENT

NAMES OF ELECTRIC UTILITY COMPANIES PARTICIPATING IN NUCLEAR POWER STUDY, RESEARCH, DEVELOPMENT, OPERATING AND CONSTRUCTION PROJECTS

PROJECTS IN OPERATION

1. Duquesne Light Co. (Shippingport).
2. Pacific Gas & Electric Co. (Vallecitos).
3. Southern California Edison Co. (Santa Susana).

PROJECTS UNDER CONSTRUCTION OR CONTRACT

4. Commonwealth Edison Co.
   Nuclear Power Group:
   - American Electric Power Service Corp.
   - Commonwealth Edison Co.
   - Central Illinois Light Co.
   - Illinois Power Co.
   - Kansas City Power & Light Co.
   - Pacific Gas & Electric Co.
   - Union Electric Co.

5. Consolidated Edison Co. of New York, Inc.
6. Northern States Power Co.
   Central Utilities Atomic Power Associates:
   - Central Electric & Gas Co.
   - Interstate Power Co.
   - Iowa Power & Light Co.
   - Iowa Southern Utilities Co.
   - Madison Gas & Electric Co.
   - Mississippi Valley Public Service Co.
   - Northern States Power Co.
   - Northwestern Public Service Co.
   - Otter Tail Power Co.
   - St. Joseph Light & Power Co.
   - Wisconsin Public Service Corp.

7. Pacific Gas & Electric Co. (HumboldtBay).
8. The Detroit Edison Co.
   Power Reactor Development Co.:
   - Alabama Power Co.
   - Central Hudson Gas & Electric Corp.
   - Cincinnati Gas & Electric Co.
   - Columbus & Southern Ohio Electric Co.
   - Consumers Power Co.
   - Delaware Power & Light Co.
   - Detroit Edison Co.
   - Georgia Power Co.
   - Gulf Power Co.
   - Iowa-Illinois Gas & Electric Co.
   - Long Island Lighting Co.
   - Mississippi Power Co.
   - Philadelphia Electric Co.
   - Potomac Electric Power Co.
   - Rochester Gas & Electric Corp.
   - Toledo Edison Co.
   - Wisconsin Electric Power Co.

9. Yankee Atomic Electric Co.:
   - Boston Edison Co.
   - Cambridge Electric Light Co.
   - Central Maine Power Co.
   - Central Vermont Public Service Corp.

PROJECTS UNDER CONSTRUCTION OF CONTRACT—continued

9. Yankee Atomic Electric Co.—Continued
   - Connecticut Light & Power Co.
   - Hartford Electric Light Co.
   - Montaup Electric Co.
   - New Bedford Gas & Edison Light Co.
   - New England Power Co.
   - Public Service Co. of New Hampshire.
   - Western Massachusetts Electric Co.
10. Carolinas Virginia Nuclear Power Associates:
   - Carolina Power & Light Co.
   - Duke Power Co.
   - South Carolina Electric & Gas Co.
   - Virginia Electric & Power Co.

PROJECTS IN PLANNING OR NEGOTIATION STAGES

11. East Central Nuclear Group.
    Florida West Coast Nuclear Group:
   - Appalachian Power Co.
   - Cleveland Electric Illuminating Co.
   - Columbus & Southern Ohio Electric Co.
   - Dayton Power & Light Co.
   - Indiana & Michigan Electric Co.
   - Indianapolis Power & Light Co.
   - Louisville Gas & Electric Co.
   - Monongahela Power Co.
   - Ohio Edison Co.
   - Ohio Power Co.
   - Pennsylvania Power Co.
   - Potomac Edison Co.
   - Southern Indiana Gas & Electric Co.
   - West Penn Power Co.
   - Florida Power Corp.
   - Tampa Electric Co.
12. Philadelphia Electric Co.
    High Temperature Reactor Development Associates, Inc.:
   - Alabama Power Co.
   - Arizona Public Service Co.
   - Arkansas Power & Light Co.
   - Atlantic City Electric Co.
   - Baltimore Gas & Electric Co.
   - California Electric Power Co.
   - Central Illinois Electric & Gas Co.
   - Central Illinois Light Co.
   - Central Illinois Public Service Co.
   - Central Louisiana Electric Co., Inc.
   - Central Power & Light Co.
   - Cincinnati Gas & Electric Co.
   - Cleveland Electric Illuminating Co.
   - Delaware Power & Light Co.
   - Detroit Edison Co.
   - Gulf Power Co.
   - Gulf States Utilities Co.
   - Hawaiian Electric Co., Ltd.
   - Idaho Power Co.
   - Illinois Power Co.
   - Iowa Public Service Co.
   - Kansas City Power & Light Co.
   - Kansas Power & Light Co.
   - Kentucky Utilities Co.
   - Louisiana Power & Light Co.
   - Mississippi Power Co.
   - Mississippi Power & Light Co.
   - Missouri Public Service Co.

PROJECTS IN PLANNING OR NEGOTIATION STAGES—continued

12. Philadelphia Electric Co.—Continued
High Temperature Reactor Development Associates, Inc.—Continued
Montana Power Co.
New Orleans Public Service, Inc.
New York State Electric & Gas Corp.
Niagara Mohawk Power Corp.
Pacific Gas & Electric Co.
Pacific Power & Light Co.
Pennsylvania Power & Light Co.
Philadelphia Electric Co.
Portland General Electric Co.
Public Service Co. of Colorado.
Public Service Co. of New Mexico.
Public Service Co. of Oklahoma.
Public Service Electric & Gas Co.
Puget Sound Power & Light Co.
Rochester Gas & Electric Corp.
St. Joseph Light & Power Co.
San Diego Gas & Electric Co.
Sierra Pacific Power Co.
Southern California Edison Co.
Southwestern Electric Power Co.
United Illuminating Co.
Utah Power & Light Co.
Washington Water Power Co.
West Texas Utilities Co.
13. New England Electric System.
14. Pacific Gas & Electric Co.
15. General Public Utilities Corp. System.

STUDY, RESEARCH, AND DEVELOPMENT GROUPS

16. Atomic Power Development Associates:
Alabama Power Co.
Baltimore Gas & Electric Co.
Central Hudson Gas & Electric Corp.
Cincinnati Gas & Electric Co.
Cleveland Electric Illuminating Co.
Connecticut Light & Power Co.
Consolidated Edison Co. of New York, Inc.
Consumers Power Co.
Delaware Power & Light Co.
Detroit Edison Co.
General Public Utilities Corp.
Georgia Power Co.
Gulf Power Co.
Hartford Electric Light Co.
Indianapolis Power & Light Co.
Jersey Central Power & Light Co.
Long Island Lighting Co.
Metropolitan Edison Co.
Mississippi Power Co.
New Jersey Power & Light Co.
New York State Electric & Gas Corp.
Niagara Mohawk Power Corp.
Pennsylvania Electric Co.
Philadelphia Electric Co.
Potomac Electric Power Co.
Public Service Electric & Gas Co.
Rochester Gas & Electric Corp.
Toledo Edison Co.
Wisconsin Electric Power Co.
Wisconsin Power & Light Co.

STUDY, RESEARCH, AND DEVELOPMENT GROUPS—continued

17. Atomic Power Engineering Group:
    - Central Illinois Public Service Corp.
    - Central Louisiana Electric Co.
    - Central Power & Light Co.
    - Interstate Power Co.
    - Iowa-Illinois Gas & Electric Co.
    - Kentucky Utilities Co.
    - Lake Superior District Power Co.
    - Northern Indiana Public Service Co.
    - Public Service Co. of Indiana, Inc.
    - Public Service Co. of Oklahoma.
    - Southwestern Electric Power Co.
    - West Texas Utilities Co.
18. East Central Nuclear Group (see item 11).
19. Minnesota Nuclear Operations Group:
    - Minnesota Power & Light Co.
    - Northern States Power Co.
20. Nuclear Power Group (see item 4).
21. Pacific Northwest Power Co. Group:
    - Montana Power Co.
    - Pacific Power & Light Co.
    - Portland General Electric Co.
    - Washington Water Power Co.
22. Puget Sound Utilities Council:
    - Puget Sound Power & Light Co.
23. Rocky Mountain-Pacific Nuclear Research Group:
    - Arizona Public Service Co.
    - California Electric Power Co.
    - Pacific Power & Light Co.
    - Portland General Electric Co.
    - Public Service Co. of Colorado.
    - Public Service Co. of New Mexico.
    - Utah Power & Light Co.
    - Washington Water Power Co.
24. San Diego Gas & Electric Co.[1]
25. Southwest Atomic Energy Associates:
    - Arkansas Power & Light Co.
    - Arkansas-Missouri Power Co.
    - Central Louisiana Electric Co.
    - Empire District Electric Co.
    - Gulf States Utilities Co.
    - Kansas Gas & Electric Co.
    - Kansas Power & Light Co.
    - Louisiana Power & Light Co.
    - Mississippi Power & Light Co.
    - Missouri Public Service Co.
    - New Orleans Public Service, Inc.
    - Oklahoma Gas & Electric Co.
    - Public Service Co. of Oklahoma.
    - Southwestern Electric Power Co.
    - Western Light & Telephone Co.
26. Texas Atomic Energy Research Foundation:
    - Central Power & Light Co.
    - Community Public Service Co.
    - Dallas Power & Light Co.
    - El Paso Electric Co.
    - Gulf States Utilities Co.
    - Houston Lighting & Power Co.
    - Southwestern Electric Power Co.
    - Southwestern Public Service Co.
    - Texas Electric Service Co.
    - Texas Power & Light Co.
    - West Texas Utilities Co.

[1] The study arrangement that San Diego Gas & Electric Co. has with General Atomic Division of General Dynamics Corp. will be discontinued if the HTRDA project, of which San Diego Gas & Electric Co. is a member, obtains congressional and AEC approval.

APPENDIX II

Plants in operation

Name of participating utility company and plant	Type of reactor	Electrical capacity of plant (kw.-e.)	Owner of reactor	Operator of reactor	Estimated cost to utility organization	In operation
(1) Duquesne Light Co. (Shippingport)	Pressurized water	[1] 60,000	Atomic Energy Commission.	Duquesne Light Co.	[2] $25,081,000	December 1957
(2) Pacific Gas & Electric Co. (Vallecitos)	Boiling water-prototype for Dresden unit.	5,000	General Electric Co.	General Electric Co.	[3] 572,000	October 1957.
(3) Southern California Edison Co. (Santa Susana).	Sodium graphite	7,500	Atomic Energy Commission.	Atomics International	[3] 1,573,000	July 1957.

[1] Initial net capacity, ultimate of 100,000 kilowatts gross expected.
[2] Includes $20.08 million for the conventional portion of the plant and the site, and $5 million toward cost of reactor.
[3] For turbogenerator portion.

PLANTS IN OPERATION

(1) The Shippingport Atomic Power Station, which is jointly owned by the Atomic Energy Commission and the Duquesne Light Co., was constructed as a part of the AEC reactor development program. Westinghouse Electric Corp. designed and built the nuclear part of the station under contract with the AEC.

Construction of Shippingport was initiated in September 1954 and completed the latter part of 1957. On December 23, 1957, a full 60,000 kilowatts of electric energy—the station's expected initial capacity—was generated and fed into the Duquesne Light Co. system.

The plant was continued in preliminary operations until July 1, 1958, when the AEC and the company concluded that sufficient tests had been conducted to demonstrate that the operating characteristics of the station were satisfactory for safe extended operation. Subsequently, the plant has been operated for long periods at full design power, demonstrating its use and reliability as a generating unit. Additionally, the plant has been used for the conduct of a test program prescribed by the AEC. Early in 1959 a training program on the operation of Shippingport will begin for representatives of domestic and foreign operations.

The Duquesne Light Co. provided the site, the conventional part of the station, and contributed $5 million toward the cost of the nuclear part. The company is operating the entire plant, including the reactor, and is purchasing the steam from the AEC at a price substantially higher than the cost of steam produced at the company's conventional plants. When the AEC selected Duquesne Light's bid, it estimated that Duquesne's participation in the Shippingport project would reduce the Government's share of the cost by about $30 million. Through 1958, Duquesne has spent $25 million for construction of this station.

(2) The Vallecitos nuclear reactor plant in California, a joint project of the General Electric Co. and the Pacific Gas & Electric Co., was started in 1956. It was completed and began feeding electricity into the Pacific Gas & Electric Co. lines the latter part of 1957. This pilot plant for the large-scale Dresden nuclear powerplant now under construction is the first entirely investor-financed nuclear power reactor project to be completed in the world. The Pacific Gas & Electric Co. furnished the turbogenerator facilities and the General Electric Co. the reactor.

(3) The sodium reactor experiment is a part of the AEC's reactor development program. It was designed, constructed, and is being operated for the AEC by Atomics International. The Southern California Edison Co. installed and is operating the steam electric plant at a cost to date of $1,573,000 and is purchasing the heat energy developed by the reactor for 45 cents per million B.t.u.

The plant was initially placed in operation in July 1957. Of major importance in this project is the company's endeavor to develop a liquid metal to water steam generator, vital to the successful generation of electrical energy from all types of sodium-cooled reactors.

Although the outlet sodium temperature of the reactor system has not been brought up to the full design temperature as yet, the operation of the steam generator and entire steam electric plant has been stable and good.

The plant has now been in operation over 2,000 hours and, in addition to withstanding and giving a good operating performance under 30 planned and accidental scrams, it has capably met all other experimental requirements of the reactor.

APPENDIX III

Plants under construction or contract

Name of organization and plant [1]	Type of reactor	Capacity of plant kw. electric	Location	Estimated cost to utility organization	In operation by—
(4) Commonwealth Edison Co.-Nuclear Power Group, Inc. (Dresden).	Boiling water	180,000	Near Joliet, Ill	$51,000,000	1960
(5) Consolidated Edison Co. of New York (Indian Point)	Pressurized water thorium converter	275,000	Indian Point, N.Y.	90,000,000	1961
(6) Northern States Power Co.-Central Utilities Atomic Power Associates (Pathfinder).	Controlled recirculation boiling water with internal nuclear superheater.	66,000	Sioux Falls, S. Dak	22,800,000	1962
(7) Pacific Gas & Electric Co. (Humboldt Bay)	Advanced boiling water	[2] 50,000	Eureka, Calif	20,000,000	1962
(8) PRDC-Detroit Edison Co. (Enrico Fermi)	Fast breeder	100,000	Monroe, Mich	78,000,000+	1960
(9) Yankee Atomic Electric Co. (Yankee)	Pressurized water-stainless steel clad fuel elements	134,000	Rowe, Mass	57,000,000	1960
(10) Carolinas-Virginia Nuclear Power Associates. (Paar Shoals).	Pressurized water-pressure tube, heavy water moderated.	17,000	Paar, S.C	28,000,000	1962

[1] Utility company members of respective groups are shown in app. I.
[2] Guaranteed. 60,000 kw. expected.

PLANTS UNDER CONSTRUCTION OR CONTRACT

(4) The Dresden nuclear power station is a project of Commonwealth Edison Co. with the cooperation of Nuclear Power Group, Inc. Major construction on the 180,000 kw. (electric) dual cycle boiling water reactor, located 50 miles from Chicago, Ill., was started in June 1957. This plant, privately financed, is being built by General Electric Co., with Bechtel Corp. as subcontractor, for a contract price of $45 million. In addition, overheads and site costs will be something over $6 million. The contract calls for completion by December 7, 1960. Construction is proceeding ahead of schedule and the project is expected to be ready for operation by the middle of 1960.

(5) The Indian Point nuclear powerplant is being financed and constructed by Consolidated Edison Co. of New York, Inc. Foundation work and erection of the containment sphere is essentially complete and other major construction work is well underway. The plant is expected to be completed by 1961.

(6) The Pathfinder project is a joint undertaking of the Northern States Power Co. and Central Utilities Atomic Power Associates. In 1957 a contract was signed with the AEC for the research, development, and construction of this project under the third round of the power demonstration reactor program. The plant will be located on the Big Sioux River near Sioux Falls, S. Dak. It is scheduled to be in operation in 1962. The plant, which will be owned and operated by Northern States Power Co., is expected to cost a total of approximately $33.1 million including research and development work. The AEC will contribute the equivalent of $10.3 million toward the cost of this project in the form of research and development work.

(7) The Pacific Gas & Electric Co. is undertaking the development and construction of a 60,000 kw. advanced boiling water reactor at Eureka, Calif. This project, scheduled for criticality on July 1, 1962, is to be financed entirely with investor funds, including research and development. Bechtel Corp. will design and construct the plant on a regular commercial contract basis. General Electric Co. will supply the nuclear and electrical equipment. The total cost of the project is estimated to be $20 million. Detailed design was started in September 1958, and field construction is scheduled to start in April 1960.

(8) The Enrico Fermi plant is sponsored by the Power Reactor Development Co. and the Detroit Edison Co. Atomic Power Development Associates, Inc., is performing research and development and furnishing the reactor design for the project. Major construction began in August of 1956 and is proceeding on schedule toward completion in late 1960. Cost of this plant to the utility organization concerned is expected to be over $78 million. The AEC is contributing the equivalent of $4.45 million toward this project, being constructed as part of the AEC first-round power demonstration reactor program, in the form of research and development work.

(9) The Yankee Atomic Electric Co. is building a 134,000 kw. (electric) pressurized water reactor at Rowe, Mass., using stainless steel clad uranium oxide fuel elements. The building to house the turbogenerator has been erected, the concrete shielding for the reactor has been completed and the 125-foot vapor container sphere is under erection. Work is well underway in the manufacturers' plants on fabrication of the nuclear reactor vessel and components and on the conventional generating equipment. The plant is expected to be in operation in 1960. The project, being undertaken as part of the power demonstration reactor program, is expected to cost about $50 million. Total requirements to be financed are calculated at $57 million, including cost of the initial core. In addition, the AEC is contributing the equivalent of $5 million in the form of research and development work toward the cost of this project.

(10) The Carolinas Virginia Nuclear Power Associates, Inc., formed in 1956, made a proposal to the AEC in August of 1957 under the third round of the power demonstration reactor program for the development and construction of a heavy water moderated and cooled pressure tube reactor nuclear powerplant. The proposal was accepted as the basis for contractual arrangements by the AEC in May 1958. The proposed plant, having a design capacity of about 17,000 kw. (net electrical), is scheduled for completion in mid-1962. A site at Parr, S.C., has been selected for its location. The associates, under the proposed agreement, would pay estimated capital costs of about $22 million. The cost of operating the plant will bring the total CVNPA expenditure to about $28 million. Total estimated costs to the AEC would be about $14.6 million.

APPENDIX IV

Projects in planning or negotiation stages

Name of organization	Type of reactor	Capacity of plant kilowatt electric	Location	Estimated cost to utility organization	In operation by
(11) East Central Nuclear Group; Florida West Coast Nuclear Group.	Gas cooled, heavy water moderated	50,000	Florida west coast area	$34,898,000	1963.
(12) Philadelphia Electric Co.; High Temperature Reactor Development Associates, Inc.	High temperature, helium cooled, graphite moderated.	30,000–40,000	Peach Bottom, Pa	[1] 24,500,000	1963.
(13) New England Electric System	Not yet selected	Over 200,000	New England		Mid-1960's.
(14) Pacific Gas & Electric Co	do	200,000	California		
(15) General Public Utilities Corp. System (Saxton)	Water type	5,000	Saxton, Pa	8,250,000	1961 (estimated).

[1] Construction of plant is on a fixed price contract.

PROJECTS IN PLANNING OR NEGOTIATION STAGES

(11) In December of 1957 a proposal was made to the AEC by East Central Nuclear Group-Florida West Coast Nuclear Group (ECNG–FWCNG) for the development and construction of an advanced heavy water moderated gas-cooled pressure tube reactor nuclear powerplant under the third round of the power demonstration reactor program. Construction of the proposed 50,000 kilowatt (electric) reactor, to be located in the Florida west coast area, would be scheduled for completion by mid-1963. The proposal was accepted as the basis for contractual arrangements by the AEC in February 1958, subject to enactment of the necessary authorization and appropriation legislation. On being so advised, ECNG–FWCNG determined to initiate the research and development immediately, with the understanding that it was doing so at its own risk pending consideration of the legislation and negotiation of a contract with AEC. The necessary legislation was adopted in August 1958. Negotiations covering the contract between ECNG–FWCNG and ABC are in the final stages. The research and development program has gone forward steadily since February 1958 and approximately $670,000 had been spent as of February 15, 1959.

(12) In November 1958 a proposal was made in response to an invitation from the AEC by Philadelphia Electric Co. in cooperation with the newly organized nonprofit High Temperature Reactor Development Associates, Inc., to design, construct, and operate a prototype high temperature helium-cooled, graphite moderated nuclear powerplant. The proposal calls for operation of a 30,000 to 40,000 kilowatt (electric) nuclear plant on the Philadelphia Electric Co. system in 1963. Construction of the plant is on a fixed price contract basis for $24.5 million. The proposal provides for the AEC to contribute up to a maximum of $14.5 million in aid of research and development. At present the proposal is under consideration by the AEC.

(13) The New England Electric System reports that it is its intention to build a large nuclear powerplant sometime in the mid-60's. The exact size of the plant will depend upon the load growth of the next several years. The unit, however, will be over 200 megawatts. The selection of the reactor type will probably be made by the end of 1961.

(14) Pacific Gas & Electric Co. reports that it is continuing to study manufacturer's proposals for a largescale reactor and that efforts will continue to be given to the project until a satisfactory conclusion is reached. The utility is hopeful that a decision on the matter can be made in the next few months. At present negotiations are underway for a suitable plant site.

(15) The General Public Utilities Corp. System has proposed the installation of a small 5 megawatts electric developmental water-type reactor at the Saxton, Pa., generating station of its subsidiary, Pennsylvania Electric Co. The reactor will be connected to existing generating equipment and will be used for conducting a research and development program with primary emphasis on achievement of cost reduction and increased efficiency in the use of nuclear fuel. One of the primary objectives of the program will be to obtain information for the design of a nuclear superheater.

The project will be a cooperative effort involving the GPU System, Westinghouse Electric Corp., and Gilbert Associates, Inc. Westinghouse will supply the reactor and associated equipment to the GPU System for a fixed price of $6,250,000. The GPU System will supply the plant site, make the existing turbine available, and bear the net operating and maintenance and insurance costs, estimated at approximately $2 million. Westinghouse will be responsible for the nuclear fuel requirements of the project for the first period of 5 years of operation, including fabrication and processing costs.

APPENDIX V

Estimate of expenditures by electric utility companies for nuclear power development [1]

	1955 and earlier	1956	1957	1958	1959	1960
Expenditures for plants [2]	$10,993,000	$25,361,000	$33,348,000	$50,112,000	$105,913,000	$89,076,000
Other expenditures [3]	2,041,000	1,592,000	2,620,000	4,816,000	4,940,000	11,047,000
Total by years	13,034,000	26,953,000	35,968,000	54,928,000	110,853,000	100,123,000
Cumulative	13,034,000	39,987,000	75,955,000	130,883,000	241,736,000	341,958,000

[1] Based on information obtained from the major nuclear power groups and previous surveys made by Edison Electric Institute.

[2] Estimate of expenditures by electric utility organizations for the following plants in operation, under construction or contract, including accompanying research and development work, but exclusive of operating costs: Santa Susana, Shippingport, Vallecitos, Dresden, Indian Point, Pathfinder, Humboldt Bay, Enrico Fermi, Yankee, Paar Shoals.

[3] Includes expenditures by individual companies and groups of companies for nuclear power study, research, and development. These figures do not include expenditures associated with any of the projects listed in footnote 2 above. Included in this category are the following groups: Atomic Power Development Associates, Atomic Power Engineering Group, East Central Nuclear Group, Florida West Coast Nuclear Group, High Temperature Reactor Development Associates, Nuclear Power Group, Pacific Northwest Power Co. Group, Pennsylvania Power & Light Co. project (up to time of cancellation), Pioneer Service & Engineering Group, Rocky Mountain-Pacific Nuclear Research Group, Southwest Atomic Energy Associates, Texas Atomic Energy Research Associates.

MEMBERS OF THE EDISON ELECTRIC INSTITUTE COMMITTEE ON ATOMIC POWER

E. L. Lindseth (chairman), president, the Cleveland Electric Illuminating Co.
J. K. Busby, president, Pennsylvania Power & Light Co.
W. L. Cisler, president, the Detroit Edison Co.
W. J. Clapp, president, Florida Power Corp.
C. B. Delafield, vice president, Consolidated Edison Co. of New York, Inc.
E. H. Dixon, president, Middle South Utilities, Inc.
P. A. Fleger, chairman of the board, Duquesne Light Co.
G. M. Gadsby, chairman of the board, Utah Power & Light Co.
R. E. Ginna, chairman of the board, Rochester Gas & Electric Co.
A. S. King, president, Northern States Power Co.
J. W. McAfee, president, Union Electric Co.
C. B. McManus, chairman of the board, the Southern Co.
I. L. Moore, president, New England Electric System.
R. G. Rincliffe, president, Philadelphia Electric Co.
Philip Sporn, president, American Electric Power Co.
J. B. Thomas, president, Texas Electric Service Co.

Senator BENNETT. Are there any questions?

Representative HOSMER. Mr. Lindseth, I note in your rather comprehensive statement about various assistance from the U.S. Government some well thought-out ideas, but I would like to know if the Edison Electric Institute has ever approached or been approached by any of the rather substantial foundations that exist in this country to give some financial assistance in development of U.S. nuclear science and engineering.

Mr. LINDSETH. The Edison Electric Institute, as such, which is the trade association of the industry has not, and neither, to my knowledge, have any member companies. However, we do have a very large number of member companies and that could have happened without my knowledge.

There has not been any publicity or discussion of it in our industry.

Representative HOSMER. These foundations are supposedly dedicated to the advancement of the general welfare of the United States, and I think thus far they have failed in their responsibility and will until they do come forward with some assistance in this field, as well as the fields they have been traditionally going into thus far.

Senator BENNETT. Mr. Van Zandt, have you any questions?

Representative VAN ZANDT. Mr. Lindseth, in your statement on page 5 you say:

> The program for nuclear power development in the United States to which electric power companies have been and are making a substantial contribution, has been progressing at a rate which is both substantial and adequate on the basis of domestic consideration.

Is this statement based on the program proposed by the AEC during the course of these hearings?

Mr. LINDSETH. No; it is not. The statement was written, actually, before I read the proposal of the AEC. It is based on the program which is in being in the industry, including projects presently under construction, under research and development, and the expectation that the progress which has been made to date will naturally continue and grow in the future.

Representative VAN ZANDT. Are you familiar with the five-point program the AEC presented to this committee during the course of these hearings?

Mr. LINDSETH. Yes; in a general way.

Representative VAN ZANDT. Do you support it?

Mr. LINDSETH. Yes.

Representative VAN ZANDT. That is all, Mr. Chairman.

Senator BENNETT. Thank you very much, Mr. Lindseth.

The next witness is Mr. Tom Pickett, of the National Coal Association.

STATEMENT OF TOM PICKETT, EXECUTIVE VICE PRESIDENT, NATIONAL COAL ASSOCIATION, WASHINGTON, D.C.

Mr. PICKETT. Mr. Chairman, my name is Tom Pickett. I am executive vice president of the National Coal Association, which is a trade organization of the bituminous mine owners and operators of the United States. Our members produce about two-thirds of the commercially mined bituminous coal in the United States.

I would like to ask, Mr. Chairman, that I be permitted to file for the record the statement that was prepared for presentation before this committee by Mr. Kenneth A. Spencer. Mr. Spencer is president of the Pittsburgh & Midway Coal Mining Co. of Kansas City, Mo.

Mr. Spencer is also chairman of the National Coal Association's Committee on Atomic Energy. The statement is brief, Mr. Chairman, but in the interest of time and in consideration of the long hours that you gentlemen have devoted to this matter today, I would like to file this statement for the record as prepared, to be presented by Mr. Spencer, together with a one-page appendix.

If that permission be granted, then I would like to summarize in 2 minutes the principal points of the statement.

Senator BENNETT. Mr. Pickett, that is a wonderful bargain for the committee. We will be very happy to accept the material offered and allow you 2 minutes.

Mr. PICKETT. I would like to add one thing further: that you spend 3 minutes reading what is in the statement.

Senator BENNETT. The Senator from Utah has read every statement he has not listened to.

(The statement referred to follows:)

STATEMENT OF KENNETH A. SPENCER CHAIRMAN OF THE NATIONAL COAL ASSOCIATION ATOMIC ENERGY COMMITTEE

My name is Kenneth A. Spencer. I am president of the Pittsburgh & Midway Coal Mining Co. of Kansas City, Mo. I make this statement in my capacity as chairman of the Atomic Energy Committee of the National Coal Association. The National Coal Association is the trade organization of bituminous coal mine owners and operators throughout the United States. Our members mine more than two-thirds of the commercially produced bituminous coal in this country.

We in the coal industry are interested in the atomic energy program because atomic energy is another source of fuel and a potential competitor with coal in the market for power-generating sources of energy.

In 1957, the generation of electricity required 157 million tons of coal, and in 1958, an estimated 153 million. This level of consumption is expected to increase to 205 million tons in 1963, unless an extravagant Federal subsidy promotes unjustified competition from atomic energy. Therefore, my testimony is restricted to item 1 on the list contained in the chairman's letter of January 27, 1959, inviting us to testify: "The Government's power reactor policies and programs, both domestic and foreign."

The National Coal Association recognizes the need for continued Government sponsorship of nuclear energy development in order to benefit humanity, further world trade, advance the cause of peace, and maintain world leadership. We believe that the Government should carry out and support basic and applied research in atomic energy. The laboratory effort should be directed to minimizing fuel processing costs, increasing the safety of reactors, and developing high temperature construction materials.

As far as the power program is concerned, we submit that economical contribution to the Nation's energy requirements should be the criterion for the use of atomic energy. Atomic generated electricity which would be economical in most areas of the United States without subsidy, direct or hidden, has not yet been demonstrated and does not appear feasible in the foreseeable future. We oppose Government subsidy of electric power production beyond the research and development stage. We think that the public should be informed (within the limitations of national security consideration) of the actual cost of nuclear fuels and the amount of Government subsidy in the development stages of the nuclear power program. Until the costs of nuclear fuel and of the safe disposal of radioactive waste are established, there can be no reliable estimate of comparative costs of power generation.

A "crash program" for domestic atomic power is both unwise and unnecessary. It would be costly to taxpayers without corresponding benefits in the form of more economical electricity. The costs of nuclear fuel are high. At the present and in the foreseeable future, the production costs of nuclear power are and will be much higher than those of power generated from coal. Even the estimated capital costs of atomic powerplants are considerably greater than those of coal plants, and so far the actual costs have greatly exceeded original estimates.

A fairly conservative estimate of atomic powerplant cost is $500 per kilowatt of installed capacity. Even the most optimistic estimates for nuclear powerplants, by this committee's staff, range from $250 to $500 per kilowatt. These figures may be compared with a cost of about $150 to $175 per kilowatt of capacity from modern coal-fired steam plants. In addition, atomic fuel costs are high. So far as is known, it has never been demonstrated that atomic fuel could approach fossil fuels in cost in most areas of this country. Even if atomic fuel were free, the high capital costs would still make atomic power prohibitively expensive inasmuch as fuel cost accounts for only about 20 percent of the total cost of electricity.

Coal is abundant as well as economical. In the United States we have reserves of about 1 trillion tons, which is enough to last at least for 1,800 years at present rates of consumption. Thus it can readily be seen that the conservation argument often advanced as a justification for developing an atomic power industry in the United States has little or no validity as far as coal is concerned. Furthermore, the efficiency of coal-burning powerplants has increased rapidly even since the advent of atomic energy and may be expected to continue to increase in the future. In 1945 it took about 1.3 pounds of coal to generate 1 electrical kilo-

watt, as compared with the present national average of about 0.9 pounds. Thus, there is no apparent need for accelerated development of new energy sources to meet domestic requirements.

There may be a need for atomic power abroad in high fuel cost areas in the comparatively near future. We recognize that other countries have less abundant coal and other energy sources than the United States. The prestige of our Government may well be involved in maintaining a position of leadership. We wish to point out, however, certain negative factors inherent in our foreign aid atomic program. First, there are certain hazards of radiation connected with the operation of atomic powerplants. In case of a nuclear accident (or "incident" as it is usually called), widespread personal injury and property damage could result, which might make the goodwill aspect of the project backfire. Secondly, most atomic power units are sources of plutonium, an important weapons ingredient, and there is always the possibility that these sources or the plutonium itself might fall into enemy hands.

The National Coal Association agrees generally with the approach taken by the Atomic Energy Commission's Ad Hoc Advisory Committee. Prototype (i.e., pilot plant) reactors should be emphasized rather than large power reactors, until the latter can be self-supporting. Contrary to some statements which have recently appeared, I do not believe that the United States has fallen behind in the race for nuclear power. The number of kilowatts of installed nuclear power is not a fair measure of a country's nuclear technology. We oppose a mere kilowatt race with other countries. On these points we agree with the ad hoc committee's report of January 1959.

We seriously question, however, the validity of the basic premise of the ad hoc committee that the United States needs to develop competitive nuclear power domestically within the next 10 to 30 years. As the committee points out, and as we have already indicated, this country has enormous reserves of coal. The reduction of the cost of atomic power to competitive levels in most areas of the United States is at most a hope. Accordingly, we disagree with the ad hoc committee as to item (d) of its objectives (p. 1 of Jan. 2, 1959, report), and submit that atomic power development, for domestic reasons alone, is neither urgent nor sensible.

Coming now to the August 1958 report of the staff of the committee, we emphasize first that this paper is a committee memorandum prepared by the staff and not a committee report. As pointed out in the introduction it "is intended as a basis for further analysis and consideration by the members of the Joint Committee and the Congress."

We earnestly believe that further analysis and consideration by your committee are appropriate. For the reasons stated above, we think the program of 21 reactors suggested by the staff is unnecessary and extravagant. We recognize the staff's assumption that only about half of these projects will prove desirable for construction, for a total of about 1 million kilowatts. Nevertheless, the total cost would be $875 million, not counting general reactor research and development costs. The latter costs would continue at a rate of $125 to $150 million per year. The Government would pay a large and as yet undetermined part of all of these costs.

We disagree with the staff's suggestion that further Government subsidies, "particularly in relation to the domestic program," should be provided. Our reasons for this position have already been stated.

Finally, we point out the obvious fallacy of the staff's statement that "the estimated cost (of the expanded program) is relatively small compared to other Government expenditures." In relative, as well as absolute, terms the cost of the domestic nuclear power development program projected by the staff would be great. If the committee agrees with our position that much of this proposed "expanded" program is not essential, it follows that this is one point where the already overburdened Federal taxpayer can be given favorable treatment.

While not claiming that the safety problem in connection with nuclear power production is insoluble, we wish to point out a few obvious difficulties. An accident at an atomic powerplant could prove disastrous. There is additional danger from enemy action or sabotage in the event of war. Under the Indemnity Act of 1957, the Government has a potentially tremendous financial liability (up to $500 million per nuclear incident). In addition to this legal liability, I am sure there would be tremendous pressure for further compensation to the victims of any so-called nuclear incident—or their survivors. If further general legislation were not enacted, I am confident there would be a flood of private

bills for special cases—and the Government would have a moral responsibility to care for those people whom it had harmed.

The cost of disposing of radioactive waste, which is a facet of the safety problem, is considerable. Testimony given just last month to your committee indicates that $200 million has already been spent on waste disposal facilities; that the United States now has 52 million gallons of high level radioactive waste stored in underground tanks, with maintenance costs exceeding $2 million; and that some waste remains radioactive for hundreds of years.

In summary, the National Coal Association recognizes the desirability of continued Government participation in the nuclear energy field but believes that this should be limited to carrying out and supporting only necessary research and development. The Government is not justified in building more large reactors than are necessary to prove technology. The Government should not subsidize domestic electric power production beyond the research and development stage and its policies should recognize that there is no need for a crash program for domestic power in this country. Within reasonable limits, the U.S. Government should continue its foreign program for the purpose of maintaining U.S. international prestige and leadership.

Now, gentlemen, I have outlined the specific reasons why we consider a crash program extravagant, unwise, and unnecessary. Now I should like to turn for just a moment to a somewhat broader discussion of this entire matter from the coal industry's viewpoint. Some of the things I will discuss are not within the jurisdiction of this committee—but they are within your jurisdiction as Members of Congress. For a complete understanding of our position, I think you must see where this question of atomic power fits into the whole picture of the coal industry and its future.

Economists generally agree that the recession is over. Let me say that this is not true of the bituminous coal industry. We are still enduring our private recession.

The reasons are many. We are whipsawed by the competing fuels and by Government policies which directly injure us. The State Department, among other Government agencies, has resisted our efforts to have import restrictions placed on the flood of cheap residual oil from Venezuela, which is displacing millions of tons of coal from major markets along the Atlantic coast. Thus, in the name of free trade, we suffer seriously from the competition of imported goods. Yet, when we seek to export coal, we face action of foreign governments which impose restrictions on shipments to our two best foreign markets. In Canada, the Government in effect subsidizes its domestic coal production by so-called subventions, in which it absorbs much of the freight cost for Canadian coal, and thus helps to undercut the price of U.S. coal on which Canadian industry has historically relied. In West Germany, our biggest customer overseas, the Bonn Government has just imposed a prohibitive tariff of $4.76 per ton on imports of coal in 1959 from the United States which exceed 4,800,000 net tons, more than half of our current rate of exports to that country. Notwithstanding the vigorous efforts of the State Department to persuade the Bonn Government not to take this drastic action, the tariff, through action of the lower house of the German Parliament, took effect February 16.

This is a case where the executive branch tried to help us. Yet in another case of injury, the executive branch does have clear authority under the Reciprocal Trade Act to impose quotas on residual oil imports—but it has not yet done so.

Within the United States, the Government allows the sale of natural gas to industrial consumers at dump rates. This unwise policy permits the wasteful use of a premium fuel to drive coal out of the market on which it has long depended.

The main bright spot in this picture is the electric utility industry. This is the biggest customer of the coal industry, and one that is expected to expand greatly in the next few years. Electric heating of homes is expected to increase rapidly and create new demands for coal. Coal now furnishes more fuel for electricity than all other fuels and waterpower combined.

Yet what you have before you, gentlemen, is a proposal to use the U.S. Treasury to help drive the bituminous coal industry out of its best market. The coal industry does not fear competition from atomic energy on a fair and realistic basis of true cost. But if the atom is reinforced by the tremendous resources of the Federal Treasury, if the cost of atomic power is cut artificially low by Federal subsidies, then the bituminous coal industry is indeed in trouble. And

by the coal industry, I mean not only the mine operators, but their thousands of workers, the railroads which derive millions of dollars from hauling coal, and the thousands of railroad workers. Whole communities could see their livelihood destroyed by lavish Federal subsidy of uneconomic atomic power.

Today there is tremendous pressure from local communities and in the Congress to pass legislation to relieve distressed areas. If the coal industry received fair and equitable treatment from its Government, we would not have distressed coal areas of the magnitude we have them today. The Treasury would not be under pressure to spend millions of dollars to alleviate suffering.

Please don't misunderstand me, gentlemen. I am acutely aware that you cannot cure all the difficulties besetting bituminous coal. However, it is certainly within your power to avoid adding to them with heavy Government subsidy of atomic energy in cases where it cannot truly pay its own way.

APPENDIX A

Our statement points out that atomic fuel costs are high. In this connection, it was stated by Dr. Robert E. Wilson, a member of the General Advisory Committee to the U.S. Atomic Energy Commission, and a recognized authority on nuclear power, in a recent article in Power Industry (January 1959) (p. 14):

"When we start to talk about the possible use of nuclear fuels in central power stations, I think it is fair to describe the present situation as confused. It is confused partly because of misunderstandings on the part of the public and partly because even the experts hold varying opinions, though not as varied as some published reports would indicate.

"According to one published claim, a plant in California will be able to make electricity in 1962 for less than 9 mills per kilowatt-hour. Another estimate predicts nuclear power costs by 1980 as low as 2 mills.

"On the other hand, electricity from the plant in Shippingport, Pa.—the only large plant in actual operation—has been said to cost 64 mills.

"The mere cost of fabricating the fuel elements—one factor often overlooked in the past—was about twice the cost of conventional power.

"For large conventional steam powerplants today, the cost range is around 3.5 to 8 mills depending on size and location."

Mr. PICKETT. The National Coal Association favors continued Government support for research in atomic power. It favors reasonable international assistance for atomic power development in accordance with the Nation's position of world leadership.

We believe that a crash program for domestic atomic power is unnecessary. We believe it is extravagant in view of the existing tremendous reserves of low-cost fossil fuels, particularly coal.

We believe that the Government subsidy of domestically generated nuclear power should be limited to the research and development stages; that subsidy should not be contributed to the production of commercially competitive power with fuels using the normal, conventional methods.

We point out in that statement, Mr. Chairman, that the generation of electricity by atomic power is uneconomical in most areas of the United States now and in the foreseeable future; that until the costs of nuclear fuel and the safe disposal of radioactive wastes are established, there can be no reliable forecast of comparative costs of power generation.

We point out further that the coal industry is whipsawed by competitive fuels and by injurious Government policies, both foreign and domestic, and we are asking, with emphasis, that this committee and the Congress do not add to our already great burden by a Government program that would further subsidize competition with a basic industry of the Nation.

Senator BENNETT. Thank you, Mr. Pickett.

Are there any questions?

Representative VAN ZANDT. Mr. Pickett, as I understand it, the National Coal Association is not opposed to the Government's program of developing the atom as long as it is confined to research and development?

Mr. PICKETT. That is correct.

Representative VAN ZANDT. But when the Government subsidizes competitive fuels, then you are opposed to that portion of the program?

Mr. PICKETT. That is correct.

Senator BENNETT. Mr. Bates.

Representative BATES. Mr. Pickett, there have been various descriptions of the type of program which is being conducted by AEC. Some think it is miserable and others think it is dynamic.

Would you testify that it is a crash program, or do you think it is miserable or do you think it is dynamic? How would you classify the program that is underway currently?

Mr. PICKETT. Congressman, I am not an expert in this type of thing. I think you will realize that. I do not consider the program that is conducted under the direction of the AEC as I understand it a crash type of program. There may be some things about it that we would not quite go along with in keeping with our basic philosophy, but certainly it is a far cry from what has been proposed by some exponents of what I consider a crash program in this field. So I do not consider the AEC program as a crash program.

Representative BATES. But for the most part it is consistent with what you think should be done?

Mr. PICKETT. Basically, I think that is correct; although, as I say, there would probably be some departures of agreement, or areas for disagreement, in that respect.

I have not studied their program in detail, but so long as it basically applies its efforts toward the research and development to the demonstration point for the purposes that they seek to achieve, and do not indulge in what I choose to call a substantial subsidization of competition with the basic fuels of this country, then we cannot have any quarrel with the principle.

Representative BATES. Of course, your argument is that there are sufficient fossil fuels in this country today?

Mr. PICKETT. Very definitely so.

Representative BATES. And for that reason, there is not the urgency associated with this program that would be present if the situation were otherwise?

Mr. PICKETT. That is certainly correct. I can see no element of urgency from the standpoint of availability or not of the fuel reserves of the country.

Representative BATES. But we should continue to develop our know-how in this area?

Mr. PICKETT. That certainly is true. We could not disagree with that at all. I would like to point out to you that the known facts, based upon the geological surveys that have been made, as applied to coal only, demonstrate very clearly that at the current rate of production and consumption, there is enough coal available at or near present costs to supply the country for the next 500 years.

There are additional reserves that would supply the Nation at a slightly higher, or perhaps a little greater than slightly higher cost for another 1,000 years after that.

Representative BATES. Thank you.

Representative VAN ZANDT. Mr. Chairman——

Senator BENNETT. Mr. Van Zandt?

Representative VAN ZANDT. The other day Mr. Sporn testified that in the year 2000, not over 20 percent of the total energy consumed at that time would be produced by atomic energy. He also said that in the year 2000 the equivalent of 855,000 tons of coal or twice as much coal as was mined in the United States in the year 1958 would be required.

While you have answered a portion of my question by telling Mr. Bates the amount of coal reserves on hand, will you comment on the National Coal Association's program of research that will produce a greater amount of heat from the coal used?

Mr. PICKETT. The association itself does not engage in research, Mr. Van Zandt. We are a trade organization and not a group of experts. However, in various fields of production transportation and consumption of coal, and in scientific and educational institutions and others that are especially equipped for that purpose, there is substantial research being carried on.

I might illustrate it briefly this way: About 1945 or 1946, slightly over 10 years ago, it took about a pound and a third of coal to produce a kilowatt of electricity. It now takes about 0.9 of a pound. That was not coal association research, but that was the result of the efforts by those large consumers of coal, those who built the combustion units in which it was fired, and others interested.

They have all developed improved methods of utilization, as well as substantially improved methods of the production of coal.

Representative VAN ZANDT. Has Government research made any contribution to the development of improved methods mentioned?

Mr. PICKETT. Well, not in the particular points that I referred to. There has been some Government research, some of which, of course, as in all research endeavors, did not prove anything that was beneficial.

Representative VAN ZANDT. Do you think that the Government has a responsibility of conducting research in coal?

Mr. PICKETT. I think the Government very definitely has a responsibility in research in coal, as well as atomic energy.

Representative VAN ZANDT. Thank you.

Chairman ANDERSON. Thank you very much, Mr. Pickett.

The next witness will be Mr. Gordon Weller.

STATEMENT OF GORDON A. WELLER, EXECUTIVE VICE PRESIDENT, URANIUM INSTITUTE OF AMERICA

Mr. WELLER. Mr. Chairman, members of the joint committee, my name is Gordon Weller. I am executive vice president of the Uranium Institute of America, incorporated under the laws of the District of Columbia, UIA headquarters being at Grand Junction, Colo.

Our organization is made up of companies and individuals engaged in exploration, production, processing, and conversion of uranium to its various useful forms. Allied industry members are drawn from numerous ancillary functions that support the uranium industry's operations.

UIA membership encompasses every uranium producing State, and we enjoy the support of companies whose corporate offices extend from coast to coast.

Like the uranium industry itself, the strongest part of the membership of the uranium institute is the independent miner or miller who, in developing properties and operations, has blazed a trail for the larger and more integrated firms to follow. These are the fellows who spend most of their time and energy in improving their operations, and administering the thousand different details that attend the conduct of any business in this modern age.

These are men who viewed the uranium industry as vast new opportunity—the kind of opportunity that could only develop in an enterprising America. They are dedicated to the principles of good business management and sound government, and they are convinced that America has the best of both.

These are men who have to be differentiated from the "fast buck" operators who were also drawn to the uranium industry a few years ago. Some of today's operators are capable mining engineers in their own right, or they have secured the services of such people and have placed them in positions of authority in their organizations. Others are practical miners who have a penchant for being on their own. They all have acquired and developed properties in the confidence that there is a reliable market for uranium ore and its refined products.

Many of these uranium operators formed corporations with investors throughout the width and breadth of America. Some were so fortunate in the course of their operations that they have grown in a remarkable way. Many have merged and strengthened their positions through diversification. Some formed corporations which brought in older mining firms with developed experience and established staffs for handling large mining and milling operations.

The reason that I take the time to describe the typical uranium operator in such detail here today is that I fear that there has developed the attitude in some circles that we now have in the uranium industry a segment of American business that has gotten its foot in the public trough—and it's going to keep it there for as long as possible. The truth is quite the reverse.

The average uranium miner and miller would give anything to be freed of his present dependence upon Government markets. He is in the business to stay—and he is basically fearful of the effects of overproduction which might later result in serious and heavy cutbacks. At the same time, during the development of the uranium industry in the past few years, he has accepted the Government's incentive programs at face value. He felt that he should not question—that he could not question the reasons behind these requirements.

He recognized that the Atomic Energy Commission itself was forging its way into completely unexplored fields, and that heavy reliance had to be placed upon a mutual trust. The term "partnership" was often used in public expressions by business and Govern-

ment officials alike, and there was an attitude of teamwork and confidence in the achievement of an important new era for the peoples of the world—the atomic age.

I am sure that you are familiar with the market assurances and incentives that were offered the industry that served as a base for this program. In my testimony before this committee last year, I included for the record circular 5, which the industry accepted as an assurance of markets for uranium ore through March 31, 1962.

I have made reference on several occasions in past testimony to the Commission's announcement of May 24, 1956, relating to the extension of these markets through the calendar year 1966, and the need for a detailed definition of this program.

You are also fully familiar with the nature of the Commission's announcement of October 28, 1957, which put the industry on notice that as of that date no further milling capacity would be authorized by the Commission except for contracts which were then in negotiation.

I am sure you remember the hardships that were made evident as a result of this precipitant notice, and the Commission's report of April 2, 1958, to this committee, wherein additional milling capacity was authorized to relieve these problems.

Finally, you will recall the Commission's notice of November 24, 1958, which was filed in the Federal Register which withdrew the guarantees of the May 24, 1956, announcement for ore discoveries subsequent to November 24, 1958, but which provided a post-1962 market for reserves which had been developed between November 1, 1957, and November 24, 1958.

The possibility of such reserve development was anticipated by Mr. Johnson of the Atomic Energy Commission when he made his first curtailment announcement on October 28, 1957, when he stated:

> The problem now is to provide an incentive for maintaining our ore reserves at approximately existing levels through replacement, by exploration and development, or the ore being mined. Much of this incentive will have to come from confidence in the future market for atomic power.

Reflecting the genuine attitude of the industry in opposition to a situation of overproduction or overdevelopment, the Uranium Institute issued a statement on November 25, 1958, immediately after the Commission's notice, describing the action as a "blessing in disguise." The notice, and the Commission administrative pronouncement that have been issued since the notice, have led the industry to an attitude of new confidence in the Commission's procurement program during this period when we have achieved a level of production that will accommodate the presently determined requirements.

It was and is the general feeling within the industry that this program is realistic, and that while it appears to impose increased controls on the industry, such controls are being accepted as necessary during this period of a satisfied market.

Almost immediately on the heels of this development, however, there have been two circumstances develop which have brought widespread consternation in the industry, and a real question as to the continued existence of the "mutual trust" we have felt we enjoyed with the Commission in the past.

The first circumstance was a report stemming from a press conference held by Chairman McCone here in Washington on January 21, in which he indicated the desirability of a "stretchout" of some of the present contracts with the industry. Such a program appears to contemplate a reduction of certain production levels during the period between now and 1962, and then an increase of such levels in the post-1962 period.

A matter of great concern to the industry in the West is the justification for this further step after the industry had just accepted what it considered to be an adequate corrective measure.

Mill contracts and mine developments have been planned on the basis of definite anticipated levels of operation. Programs for financing these operations and employment and capital commitments which have been made did not anticipate any deviation from these levels.

Those of us in the uranium industry have to confess a deplorable state of ignorance on this plan. While the Commission has made its thoughts on a plan for stretchout of uranium production known to the Washington press corps, and to you members of the Joint Committee in executive session, those of us in the industry continue to have to rely upon rumors and secondhand reports as to the exact nature of these plans.

Senator BENNETT. Have you seen the statement released today by the Commission, discussing that part of the hearings of the subcommittee which cover the point that you are just mentioning?

Mr. WELLER. Are you referring to Mr. Johnson's testimony?

Senator BENNETT. Yes.

Mr. WELLER. I did see that testimony just today; yes, sir.

Senator BENNETT. Then do you still want the record to say that you have to rely on rumors and secondhand reports?

Mr. WELLER. Yes, sir; I do.

In the first place, we urged that this information be made known at the time that the testimony was given the committee and, secondly, I am not sure that that testimony, as I have read it, includes a complete description of the effects of the stretchout program.

Senator BENNETT. It includes everything that the committee feels can be declassified.

Mr. WELLER. This, then, continues to be a problem for the domestic industry, because we do need more information than we are getting at the present time, Senator.

The second circumstance I have to report to you has rocked the uranium industry to its very core. This relates to the attitude which has been made evident by the Canadian uranium industry that the present U.S. purchase commitments should be extended from their present terminal dates in 1962 and 1963 to the end of the calendar year 1966.

Coupled with these reports are the observations from such qualified industry news media as Engineering and Mining Journal, reporting that: "Prediction is that they (the U.S. AEC) will buy."

Mr. Chairman, I submit for the record a copy of a report prepared by the Uranium Producers Committee of the Canadian Metal Mining

Association, addressed to the Prime Minister of Canada and the members of his cabinet, urging that—

> the Canadian Government do everything in its power to have the Government of the United States exercise its options on Canadian uranium production up to December 31, 1966, and give, at the earliest possible date, notification of its intention to do so.

Mr. Chairman, I think there has been testimony submitted at this hearing that perhaps the issuance of this report is the equivalent of the call of wolf. I submit to you that it is the duty of any trade association to make known to its members all of the activities that are going on that might affect its markets. This we have sought to do.

As you know, we have consulted with you and every other source where we might secure accurate information concerning these matters. We have been advised that the Commission is quite inclined to hold within reason any future contract commitments.

We do feel, however, that there is pressure being exerted from that particular market development possibility, that we have to make our attitude known to you gentlemen of the Joint Committee and to the officials of the Atomic Energy Commission.

Gentlemen, you have already been apprised of the price disparity which has existed between the domestic uranium industry and Canadian and foreign producers.

This matter of concern was brought before an industry meeting sponsored by the New Mexico Economic Development Commission in Albuquerque on December 9, 1957. In response to some rather searching questions raised by Congressman John Dempsey, a former member of your committee, Mr. Jesse Johnson, told the industry:

> Now, in 1955, early in 1955, we could see the Canadian production going up, we could see more profitable development in the United States, and before the Ambrosia Lake was discovered, we agreed with Canada for a cutoff on any additional purchases from Canada. This was in the spring of 1955 and announced in Canada about July.

Two weeks later, Gen. K. E. Fields, former General Manager of the AEC, responded to an inquiry of Senator Arthur V. Watkins with a letter dated December 23, 1957, later published as a part of the 202 hearings last year (p. 199, Problems of the Uranium Mining and Milling Industry). Said General Fields:

> Imports from Canada are expected to be on the order of 10,000 tons of U–308 in the current fiscal year, and thereafter, at a rate of 13,000 to 14,000 tons of U–308 annually until March 31, 1962. Some of our Canadian contracts extend to March 31, 1963, but the major portion of contract quantities deliverable during this additional period will be purchased by the United Kingdom in accordance with an agreement to which the United States, Canada, and the United Kingdom are parties.

Mr. Chairman, reliable reports now indicate that Canada will ship more than 16,000 tons of U–308 to the United States in fiscal year 1960. I should like to inject that I did note in Mr. Johnson's statement that this quantity would be in the amount of 13,800 tons, I believe. I will accept a correction on this part of my statement. The information which I drew this from, however, is indicated in the testimony which follows.

This information is contained in the January 30 issue of the London Mining Journal, which has been made available to the industry by

the Utah Mining Association. It is confirmed by the report which I have given you which was prepared by the Canadian Metal Mining Association.

This report estimates that $350 million of uranium will be sold to the United States in the coming year. At the current price paid Canada, this would amount to 16,600 tons of uranium oxide.

If AEC officials only a year ago pegged future Canadian production of 13,000 to 14,000 tons of oxide, and if they also reported that increased purchases from Canada were cut off, we ponder the reasons as to how our neighbors to the north were able to achieve this increase at the time that the domestic industry was being subjected to increasing pressure and control.

Furthermore, we find it difficult to understand how such purchases could be justified when they could be purchased in the United States at a savings to the taxpayer of about $5 million, based upon our price differential.

Gentlemen, this is a matter of gravest concern to the domestic uranium producer. We have reported to the industry the actions of the Canadian Metal Mining Association, and within 1 week's time after the initiation of a petition opposing further purchases of nondomestic uranium, more than 1,200 signatures were returned to our office in a groundswell of protest against such procurement.

Every uranium mill operator in the West was required to agree to conformance with the Buy American Act in the construction and operation of his mill, as a condition to his contract with the AEC. We respectfully submit it is now evident that the conditions of the Buy American Act must be applied to the Atomic Energy Commission in its program for the purchase of uranium.

We ask that specific legislation be enacted to prevent the further purchase of uranium from nondomestic sources beyond this Nation's present commitments while restrictions continue to be imposed on production from the domestic industry.

Mr. Chairman, we appreciate this opportunity to report these problems to your committee, and solicit your cooperation to bring about the proper corrective measures.

Chairman ANDERSON. On page 2 of your statement, where you quote Mr. Jesse Johnson, what you read about replacement by exploration and development or the ore being mined did not sound quite right. I sent for a copy of Mr. Johnson's statement. It is "of".

Mr. WELLER. Yes. That was a typographical error.

Chairman ANDERSON. We will note for the record that we have here the reports. I presume you want to take them with you. They are the reports from the operators.

Mr. WELLER. Yes, sir.

Chairman ANDERSON. We will receive for the record this message from the Canadian Metal Mining Association with reference to the purchase of ore.

(The document referred to follows:)

CANADIAN METAL MINING ASSOCIATION

Rt. Hon. JOHN DIEFENBAKER, P.C., M.P.,
Prime Minister of Canada.
Hon. DONALD M. FLEMING, P.C., M.P.,
Minister of Finance.
Hon. GORDON CHURCHILL, P.C., M.P.,
Minister of Trade and Commerce.
Hon. SIDNEY SMITH, P.C., M.P.,
Secretary of State for External Affairs.

MARKETS FOR CANADIAN URANIUM

HONORABLE SIRS: On behalf of the private producers of uranium in Canada, we appreciate having this opportunity of drawing to your atention certain problems which confront the uranium producing industry, and particularly the position in which the industry may find itself upon the expiry in 1962 and 1963 of the current sales contracts with Eldorado Mining & Refining, Ltd.

The growth of the uranium mining industry and its importance in the Canadian economy

The Canadian uranium mining industry has grown during the last 3 years at a spectacular rate and now ranks first among metal and mineral producers in Canada as a dollar export earner.

During the first 8 months of 1958, uranium exports have amounted to 5 percent by value of all Canadian commodities exported. The rapid growth of the industry is shown by the fact that the value of uranium exports for all 1957 totaled $131 million, whereas during the first 10 months of 1958 the corresponding figure was $215 million. During 1959, with all established mines and mills having government contracts reaching production, uranium exports are expected to exceed $350 million.

Eleven mines and mills, with a total milling capacity of 35,000 tons of ore a day, in the Blind River-Algoma area; four mines and three mills, with 3,700 tons of ore a day, in the Bancroft area; six mines and two mills, with 2,750 tons of ore a day, in the Beverlodge area, and one mine and mill, with 150 tons of ore a day, in the Northwest Territories, have been brought into production by private companies within the past 5 years.

New townsites have been created, which provincial governments as well as the mining companies have played a notable part in developing, and which are almost entirely dependent on the uranium mining industry. Of particular note is Elliot Lake in northern Ontario, with 27,000 inhabitants gaining a livelihood directly or indirectly from uranium production.

Government contracts for the sale of uranium

Private producers of uranium hold contracts valued at $1½ billion with Eldorado Mining & Refining, Ltd., which in turn holds contracts for a similar amount with the U.S. Atomic Energy Commission. The United States is thus by far the principal buyer of Canadian uranium.

The U.S. Atomic Energy Commission has agreed, since conclusion of the contracts, to a diversion to the United Kingdom Atomic Energy Authority of a certain part of the deliveries which would otherwise have been made to it. However, these are diversions within the overall quantities of the contracts and do not constitute additions to them.

Uranium producers in Canada, and indeed throughout the free world, believe that the next 10 years the market for uranium for civilian purposes, as distinct from military uses, will be small in relation to the productive capacities of the mines. This opinion is based on a comprehensive study of civilian nuclear power reactor programs throughout the free world. Ten years from now prospects for the sale of uranium for civilian use appear more encouraging, and by that time the demand should be sufficient to provide a reasonably adequate outlet for Canadian uranium on world markets.

There remains, nevertheless, the likelihood of a demand gap after the expiry of present Eldorado contracts in 1962 and 1963, and until the late 1960's.

Atomic Energy Commission options on Canadian uranium production in the post-contractual period

The U.S. Atomic Energy Commission holds options on a considerable portion of potential uranium output from Canadian mines in the postcontractual period up to December 31, 1966. These options are exercisable up to March 31, 1961. As the Canadian industry was developed at the urging of the U.S. Government, to satisfy the needs of that country for vital sources of uranium oxide, we sincerely trust that the AEC will purchase Canadian output, at least up to the optioned amounts, until December 31, 1966.

As the civilian market for uranium up to 1966 will be very limited, it is of vital importance to the Canadian uranium industry that these options be taken up. It is respectfully requested that the Canadian Government examine this situation and bring to the attention of the United States Government the imporance it attaches to the taking up of the options before March 31, 1961, and the desirability of giving notification of its intention to do so at the earliest possible date.

Private sales of uranium

We now turn to consider private sales of uranium by Canadian producers, as distinct from sales contracts between private producers and Eldorado Mining & Refining, Ltd.

Private sales of uranium, surplus to Government contracts, may now be made, subject to current regulations. Some Canadian mines are already capable of producing such a surplus, which they are naturally desirous of marketing.

With regard to the present regulations governing the private sale of uranium, producers are at pains to stress that such private sales alone cannot solve their marketing problem for the next decade. While it is essential that producers get well-established in as many oversea markets as possible through private sales, we are confident that the main problem, namely, the continued operation of uranium producing mines, can be solved only by having the U.S. Government exercise their postcontractual options.

The present regulations were announced by the Honorable Gordon Churchill in a statement in the House of Commons on May 7, 1958. A copy of this statement is appended. These proposals, which were welcomed by the industry, announced a change in Government policy whereby the private producer can make his own arrangements for the sale of surplus uranium under certain conditions.

The new regulations have been in force for a short time only. But the experience already gained indicates that the quantitative limitations which the regulations impose are proving an impediment to business and a deterrent, obstructing Canada's development as a future large-scale supplier of uranium to foreign markets.

A limit of 2,500 pounds of uranium is now established as the maximum sale which can be made to any country which has not concluded with Canada a bilateral agreement for cooperation in the peaceful uses of atomic energy.

Lack of bilateral agreements

This 2,500-pound limitation would be viewed with greater equanimity by Canadian uranium producers if the number of bilateral agreements already concluded was substantially greater, if the prospects of concluding further bilateral agreements in the near future were hopeful, and if there was confidence that other countries would adhere to the same limitations.

As it is, Canada has bilateral agreements only with the United States, the United Kingdom, West Germany, and Switzerland. The United States is now the largest producer of uranium in the world, and therefore it is unlikely that that market will offer any outlet to Canadian producers for private sales. The United States is in fact a competitor in the field of private exports of uranium.

In the United Kingdom, the Atomic Energy Authority is the sole purchaser of uranium, and Britain's requirements are covered by intergovernmental contracts.

The potential market for uranium in Switzerland is judged to be small. Of those countries with which Canada has bilateral agreements, there remains only West Germany as a market to which Canadian private producers may hope to sell uranium in commercial quantities at the present time.

As regards private exports of uranium, Canada's principal competitors are the Union of South Africa, the United tSates and, to a lesser degree, Australia and the Belgian Congo. It is, therefore, a matter of concern that private producers

in the United States enjoy a preferred position with their own Government and have a far greater range of potential markets, as the U.S. Government has concluded bilateral agreements with 12 other countries, and five further agreements are signed and await ratification. The conclusion, pending U.S. congressional ratification, of a bilateral agreement between the United States and Euratom aggravates the difficulty. It facilitates sales by the United States in the largest potential market outside the United States and the United Kingdom.

Countries anxious to develop nuclear power programs have a greater incentive to conclude bilateral agreements with the United States than with Canada, because of the greater benefits which the powerful atomic energy industry in that country, strongly backed by its Government, can offer. In addition to offering high-quality technical assistance, the United States is also the sole supplier of enriched uranium. In concluding bilateral agreements with the United States, other countries are automatically invited to obtain commercial quantities of uranium from the United States.

Canadian producers appreciate the efforts which have been and are being made by the Government of Canada to persuade potential foreign users of Canadian uranium to enter into negotiations for the conclusion of bilateral agreements with this country. Unfortunately, however, there seems to be serious opposition to the conclusion of such agreements. It is understood that strong objection attaches particularly to the principle of supervision, or control of end use of uranium, by the selling country. We understand that this is the factor which has induced the French Government to develop their own resources to the point of self-sufficiency.

While fully appreciating the purpose of the supervision clauses and agreeing with the underlying principles, we submit that conditions have changed in recent years and that a different approach to the problem is now warranted. Effective control over the production and end use of uranium cannot be exercised indefinitely in the free world by the present major uranium producing countries, the United States, Canada, and South Africa. Uranium is not a scarce mineral; nuclear knowledge is no longer contained by national boundaries. Further, the enormous cost of developing nuclear weapons, compared to the relatively insignificant cost of the uranium needed, constitutes the only real deterrent to smaller countries which may wish to develop such projects.

As for uranium, intensive geological exploration in recent years has revealed the existence of workable deposits in many parts of the free world. The fact that some of these deposits cannot be developed as economically as the large concentrations of ore located in Canada, the United States and South Africa, has not prevented their exploitation. In fact, under present conditions, the insistence on bilateral agreements as a condition of the sale of uranium overseas, encourages potential users to seek and develop their domestic deposits without regard to economic considerations.

Serious competitive threat of other uranium producing areas

The immediate potential market for private sales of uranium is undoubtedly small and will probably build up to a large demand only over the next 10 years. The aim of the Canadian producer, therefore, is to gain a fair share of what market there is.

Canadian uranium producers have been diligent and, in part, successful in developing trade prospects, but they have been prevented from taking advantage of them by the present limitations and prohibitions, at a time when other countries are reported to be offering uranium products for sale abroad with no strings attached.

Need for maximum Government support of private uranium sales

The importance of uranium to the Canadian economy has been referred to already. However, the future life and continuing operation of the Canadian uranium mining industry depends almost entirely on the existence of Government contracts which expire in 1962 and 1963. The need to develop markets for private sales after the expiry of Government contracts is clear and has been concerning the industry for some time. It is perhaps worthwhile to recall how the Canadian industry is placed, with regard to Government contracts, in relation to the other major producing countries.

U.S. producers have a guaranteed market until December 1966. South African Government contracts do not expire until 1964–66. The contract of the major Australian producer extends until 1965. In addition to the need for finding a private market at an earlier date than our foreign competitors, most Canadian

producers suffer from the additional disadvantage of having higher production costs than many U.S. producers and the majority of South African producers. Average grade of ore in the U.S. mines is about 5 pounds of U_3O_8 per ton, compared with 2.5 pounds in Canada. Although the ore grade in South Africa averages only 0.5 pounds per ton, South African production costs tend to be lower than in Canada, as uranium is produced as a byproduct in gold mining operations.

These are among the reasons why the uranium producers call upon the Government to provide the international machinery which will enable them to sell their products abroad and otherwise to put them on all fours with their competitors in other countries as regards the duration of Government contracts.

Encouragement of nuclear power developments in Canada

Very substantial research has been and is being undertaken by private industry in this country, with a view to hastening the day when electrical energy can be supplied by nuclear reactors powered from uranium.

It is clear that in the near future the need for more extensive power resources will continue to be increasingly felt in the more populous and highly industrialized areas and Provinces of this country. Careful consideration should be given to the possibility of developing electrical power by nuclear reactors, which would enable some portion of our domestic uranium production to be put to work in this country, thereby avoiding the large importations of coal, with the necessary adverse effect on Canada's balance of trade with the United States.

In particular, the rapid development of northern Canada is now the avowed policy of the Federal Government. The generation of power by nuclear reactors in northern areas and communities could offer a feasible and economic solution to what is otherwise a very serious problem.

The Government of Canada might well examine carefully the feasibility of such development as part of its program for the economic advancement of the Canadian North.

Recommendations

To assist and facilitate the freer marketing of Canadian uranium it is therefore respectfully recommended that—

1. the Government of Canada do everything in its power to have the Government of the United States exercise its options on Canadian uranium production up to December 31, 1966, and give, at the earliest possible date, notification of its intention to do so;
2. the Government of Canada take the initiative at the earliest possible date in extending bilateral agreements or in providing other international machinery which would enable Canadian producers to sell more uranium products abroad;
3. as an immediate measure, the Government permit the quantity of natural uranium which may be sold without a bilateral agreement to be increased from 2,500 pounds per country to at least 25 tons;
4. the Government of Canada give consideration and encouragement to the possibility of the establishment in this country of power resources developed from nuclear reactors.

Respectfully submitted.

URANIUM PRODUCERS COMMITTEE,
Canadian Metal Mining Association.

APPENDIX

STATEMENT BY HON. GORDON CHURCHILL, MINISTER OF TRADE AND COMMERCE, ON WEDNESDAY, MAY 7, 1958

On February 1, 1958, I advised the House of Commons that on the basis of present information it was expected that certain Canadian uranium mines would be able to produce in excess of the rates specified for delivery in their contracts with Eldorado Mining & Refining and I stated that every effort would be made to sell this surplus uranium to individual friendly countries and to organizations of friendly countries.

"Up to the present time, it has been the Government's policy that Eldorado Mining & Refining, Ltd., be the sole buyer and seller of uranium produced in Canada.

"The Government has now decided to amend this policy to permit the private producer to make his own arrangements for the sale of any uranium which

Eldorado is satisfied will be surplus to his contract requirements with Eldorado, subject to the condition that export permits will be obtained from the Atomic Energy Control Board and the Department of Trade and Commerce. Permits may be issued for individual sales of up to 250 pounds for use in testing and research, but the total of such sales to any one country must not exceed 2,500 pounds unless the goverment of the recipient country has entered into an agreement with the Canadian Government for cooperation in the peaceful uses of atomic energy. Permits for sales of larger quantities will normally be issued for export to countries with which Canada has such an agreement.

"It is very much in Canada's interest that the uranium which is sold under these arrangements should be in as finished a form as possible. Eldorado now has in operation facilities for the production of uranium oxide and metal and private facilities are available for the fabrication of fuel elements. These facilities can be made available to the producers on a custom basis. This will make it possible for the producer to offer a finished product to the customer. It is the Government's hope that this change in policy will help to develop new markets for Canadian uranium."

Chairman ANDERSON. Are there any questions?

Senator BENNETT. No; I have no questions.

Chairman ANDERSON. Mr. Wilson will be the next witness.

Senator BENNETT. Mr. Clark L. Wilson is one of the outstanding mining operators in the State of Utah. Since 1940 he has been connected with the Newpark Mining Co., of Park City, Utah, which recently has diversified its activities to include the Silver Buckle Co., a mining company of Salt Lake, whose uranium operations are taking place in eastern Washington.

Senator Jackson was here a good part of the afternoon, but he was sorry that he had to leave and could not hear Mr. Wilson's testimony. I have very high respect for Mr. Wilson and I am happy to present him to the committee.

Chairman ANDERSON. Thank you, Senator Bennett.

I think that is a fine introduction for you, Mr. Wilson, and you may proceed.

STATEMENT OF CLARK L. WILSON, VICE PRESIDENT AND GENERAL MANAGER OF SILVER BUCKLE MINING CO., SALT LAKE CITY, UTAH

Mr. WILSON. Mr. Chairman, I have submitted the statement to the committee. If you would like to have me summarize it in a few minutes, I will be happy to do so.

Chairman ANDERSON. You may proceed with your statement.

Mr. WILSON. I am here today representing one of the few independent mining organizations, small organizations, still left in business in the West.

A year ago I appeared before this committee requesting help in a mill contract allocation for a large ore body that we had developed on the Spokane Indian Reservation. However, as a result of this hearing and the recommendations by the AEC, it was requested that we ship our ore on a custom basis to the already established Dawn mill of the Dawn Mining Co. We proceeded to do that this year, but have not been very successful, economically.

It turns out that the Dawn ore body, mined by the Dawn Mining Co., apparently is assaying roughly sixteen one-hundredths of 1 percent U^{308}. We, as a custom customer, are required to ship 0.20 U^{308}. In other words, we must high grade our ore and ship it to the mill

which we think benefits them. We have expended over a half million dollars in this project. We find we are going into the hole. We think some very easy remedies can be effected that would keep us in business. These have been summarized on the last page of our testimony.

In effect, we think that the AEC has responsibilities to us in arranging our request as we did operate under the originally announced AEC program, and had submitted a genuine, complete mill request prior to the Jesse Johnson speech of October 28, 1957.

We think we should have a long-term tonnage contract. We think that our minimum mill head assay should be, say, sixteen one-hundredths, comparable to that of the mill ore body.

We think that perhaps the Dawn-AEC contract should be amended to permit full use of their mill in giving us larger daily tonnage of ore than presently have been allocated to us.

My statement reads as follows:

Mr. Chairman, on February 28, 1958, I testified before this committee as an officer of the Northwest Uranium Mines, Inc. For the benefit of this committee I would like to present a brief résumé of those remarks and discuss recent developments since that time.

Northwest Uranium Mines, Inc., was a small independent organization owned by 3,000 stockholders and established to prospect, develop, mine, and process uranium ores. The company was organized in early 1955 and prospected 100,000 acres of potential mineral ground with aerial radiometric and ground surveys. Our efforts were concentrated in the northwest portion of the United States and led to discovery of a large uranium ore reserve on the Spokane Indian Reservation.

The schedule of development of this reserve was affected by formulation of new Spokane tribal prospecting rules—an especially hard winter in 1955–56, and negotiations with the Defense Minerals Exploration Administration for an exploration loan.

The uranium reserve was drilled our during 1956 and we received one of the first Spokane tribal mining leases in February 1957. We retained Mr. R. R. Porter of Salt Lake City, one of the outstanding uranium metallurgists in this country, to test these ores, design a mill, and prepare our presentation for a concentrate contract with the Atomic Energy Commission.

Negotiations on methods and costs were initiated with the AEC in Grand Junction, Colo., by Mr. Porter and myself on January 3, 1957, and were followed by further visits and telephone calls. The large ore reserves of the Northwestern United States are lower grade than in other areas of our country, but these reserves are chemically amenable to treatment, and uranium can be produced on a competitive basis with other U.S. ores.

We submitted our application for a concentrate purchase to the AEC in July 1957.

Further information on the final cost of the final product was submitted to the Grand Junction office in early October 1957. The AEC was kept fully informed at all times of our program, and we felt that ours was a sound program leading to a concentrate contract based on rules and policies of the Commission.

Following the October 28, 1957, announcement of policy change, our attorney conferred with the Washington, D.C., AEC office and obtained the impression that our case was still receiving favorable consideration.

In November 1957, I was informed here that we should try to work through the mill of the Dawn Mining Co. at Ford, Wash. In January 1958, we were finally told that there could be no mill for the Northwest Co.—this after 3 years of work and expenditure of over $350,000.

We proceeded to negotiate with Dawn Mining Co. on the basis of participation in their mill operation. The grade and quantity of our ore reserve would require a large daily tonnage to guarantee a profitable operation. Dawn was interested in our proposals but needed the following adjustments in their contract, requested by us at the hearing last February.

(1) Extension of the total number of pounds of U^{308} as concentrate which Dawn may deliver to the Commission at its contract price.

(2) Amortization by AEC of expanded milling facilities for accommodation of Northwest ores.

(3) Revision of existing milling tonnage limitations and contract termination date.

(4) Application of circular 5 prices to ores processed under the proposed agreement between Northwest and Dawn subsequent to the announced expiration date of the program—March 31, 1962.

Last February, Northwest asked that consideration be given these requests by the Commission through action of this committee.

Development since February 1958: Under date of March 31, 1958, the Division of Raw Materials of the Atomic Energy Commission, furnished this committee "A Report on the Domestic Mining and Milling Problems Resulting From Limitation on Additional Milling Capacity by the Division of Raw Materials of the Atomic Energy Commission."

This report expressed the opinion of the AEC that:

The mill capacity at the plant near Ford, Wash., should be adequate to process all presently indicated and inferred ores in the district by early 1965.

Further—

Present mill capacity is approximately 400 tons per day, of which 100 tons per day are available for custom ores.

The AEC indicated and inferred ore reserve, for the entire district on November 1, 1957, was given as 1,038,000 tons, assaying 0.19 percent U^{308}. Our own ore estimate included in our concentrate contract submission of July 13, 1957, was 603,000 tons at 0.124 percent U^{308}.

Based on this data and published information on Dawn Mining Co. Mill results—7 months production to March 31, 1958, mill ore assay 0.167 percent U^{308}—it appears that the AEC calculations were based on a high-grading type of mining operation and they were not considering the production of the maximum amount of uranium available. A combination of 100 tons per day custom ore capacity and a 1965 finish date involves extension of payments of circular 5 prices and haulage allowance by the mill in treating custom ores during the 1962 to 1965 period. The economics of independent mine operations will be seriously affected during this period unless there is an adequate crude ore price comparable to schedule 5.

As a result of the Commission report, Northwest studied the possibility of shipping ore on a custom basis. Dawn Mining Co. agreed to issue a 1-year ore purchase contract based on 60 tons per day since we were the only other potential large producer in the area, but they required our shipments to be in 350-ton lots, having a minimum assay value of 0.20 percent U^{308}. This reduced our mineable ore reserve to 158,000 tons with a minimum stripping ratio of 12 waste to 1 ore, and only 42 percent of the uranium in the property could be extracted. We negotiated with Dawn Mining Co. for a longer contract—greater daily tonnage, lower assay minimums, and monthly grade averages—all necessary for successful operations, but were unable to obtain concessions. Apparently the AEC could give us no protection even though they had refused our bid for a mill, and yet indicate the policy of protecting the interests of the independent miner.

Northwest had depleted its capital in exploring, drilling, mill testing, and AEC negotiation, so could not proceed with the mining under the Dawn Mill contract.

The Northwest Co. assets were sold last May 1958, to Silver Buckle Mining Co., of Wallace, Idaho, the largest stockholder, and the operation has proceeded under Silver Buckle management.

Initial open-pit mining has been in the area of deepest cover but in the best grade ore, and has resulted in a high stripping ratio with a resultant larger capital investment. Shipments were started to the Dawn Mill in August, and amounted to 8,867 tons in 1958. Dawn Mill permitted us to ship up to 100 tons per day when no other custom ores were available to them. Our initial mining cycle for this winter season required stripping of 380,000 yards of waste to produce approximately 20,000 tons of salable ore—over 0.20 percent U^{308}—and approximately 15,000 tons of lower grade ore that cannot be shipped under the mill minimum requirement.

Silver Buckle is presently investing additional capital in screening equipment to remove waste rock and mechanically upgrade stockpiled ore. Our mill tests indicate that this may be possible. In addition to ore tonnages given above, we have an estimated 30,000 tons of material that will assay 0.08 percent U^{308}. This high-grading type of mining operation has several economic effects. Selective mining for grade involves stripping of separated ore bodies. Separate pit entrances increase the waste to be removed and affect costs correspondingly. During the mining cycle, we segregate ores according to average grade—for example, those assaying 0.20 percent U^{308} and better, those assaying 0.15 percent to 0.20 percent, 0.10 percent to 0.15 percent, and below 0.10 percent.

It requires just as much waste removal to mine and ship the tonnage assaying 0.20 percent as it does to produce all the grades mentioned above. Under present shipping restrictions the lower grades are waste in our operations but must be removed from the pit in the mining cycle. In effect, this is uranium being thrown away. By reducing our minimum grade requirement to 0.16 percent U^{308}, ore tonnage available will increase 2½ times, pounds of uranium produced will double, and the stripping ratio will be cut in half. The economics of the entire operation will improve.

Our financial experience to date indicates that the mill requirement of a minimum assay of 0.20 percent U^{308} on each lot makes the entire

ore body noncommercial, and puts the independent miner out of business.

Correspondence with Mr. Allan E. Jones, Grand Junction operations manager, indicated that the custom ore market—

should be available for amenable ores having an average grade commensurate with that used in negotiating the plant contract.

Again, the published mill figures of the Dawn Mining Co. indicate a head assay of 0.167 percent U^{308}, including some higher grade custom ores. In other words, the custom ore producer must high-grade his ore body to upgrade the Dawn Mining Co. production. If uranium were sold on an open market and Dawn Mining Co. had no Government contract to guarantee amortization of their capital, they would be in a position to treat us as they please. Under the circumstances of (1) Dawn having an AEC contract for concentrate purchase through 1962, and (2) considering the past history of negotiations by Northwest Uranium Mines, Inc., to obtain a mill for the Peters Lease ore body—operated by Silver Buckle—with AEC refusal, we believe there is an obligation by Dawn, through the AEC, to purchase the largest possible custom ore tonnage at a minimum grade requirement commensurate with their own mine average.

We have continued negotiations with Dawn Mining Co. and they are willing to reduce the minimum assay to 0.19 percent U^{308}, and average lots on a monthly basis.

However, if Silver Buckle drops below the minimum assay in any one month, we would again be in negotiation with Dawn as to the penalty.

We appreciate their concession, but it is not sufficient. In view of our history of effort and expenditure of $600,000 in the uranium program, we request the AEC to—

(1) Authorize a long-term custom ore tonnage contract between Dawn Mining Co. and Silver Buckle Mining Co. We are entitled to this based on AEC procedure to protect those already in the business.

(2) AEC should insist that Silver Buckle be permitted an average minimum millhead assay of at least 0.16 percent U^{308}. This will increase minable ore reserves to 416,000 tons and permit 81 percent extraction of the U^{308} in the ground.

(3) To mill this reserve by 1966 the Dawn AEC contract should be amended to permit full use of their present mill capacity and Silver Buckle be given a much larger daily tonnage allocation than presently available.

(4) We would expect monthly average assays to be used for all shipments treated and our agreement should specify procedures for deviations below this minimum.

Mr. Chairman, the officers and directors of Silver Buckle Mining Co. feel very strongly that the AEC has a direct responsibility in our situation, and we request the assistance of your committee in authorizing our requests.

I thank you.

Chairman ANDERSON. Thank you, Mr. Wilson. Some time ago some of the producers in Wyoming, western North Dakota, and South Dakota asked us to help them. We did arrange a meeting with the AEC and it worked out to their advantage, and I hope to the ad-

vantage of the Government. I am sure the members of this committee will be glad to help you.

Mr. WILSON. I might say that we have sent some phase of these requests to both Mr. Allan Jones in Grand Junction, and personally to Mr. Jesse Johnson. But now we need some action.

Chairman ANDERSON. We will see what action we can take for you. Thank you very much for coming.

(The following is an exchange of correspondence pertaining to Mr. Wilson's testimony:)

SILVER BUCKLE MINING CO.,
Wallace, Idaho, March 12, 1959.

JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Capitol Building, Washington, D.C.

DEAR MR. RAMEY: I wish to thank you for your letter of March 6 suggesting that you would like to incorporate in the committee record of 202 hearings my letters, dated March 3, to Senator Anderson, and February 28, addressed to Mr. Jesse C. Johnson.

We appreciate your suggesting this and would be very happy to have these two items included.

Very truly yours,

SILVER BUCKLE MINING CO.,
CLARK L. WILSON,
Vice President.

SILVER BUCKLE MINING CO.,
Wallace, Idaho, March 3, 1959.

Senator CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy,
Senate Office Building, Washington, D.C.

DEAR SENATOR ANDERSON: I wish to again thank you for courtesies extended at the time of my appearance before the Joint Committee on Atomic Energy during your sessions last week.

Last Friday, I had a telephone visit with Mr. Jesse Johnson regarding our situation, and he suggested I summarize my thoughts in a letter to him and asked for copies of my testimony in behalf of Silver Buckle Mining Co.

I am enclosing a copy of the letter to Mr. Johnson and you will note that we have pretty well summarized the basic issues. As indicated in the letter and in our testimony, we feel that our request has merit and the AEC has responsibilities to us.

Your consideration of our situation will be greatly appreciated.

Very truly yours,

CLARK L. WILSON, *Vice President.*

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C., March 6, 1959.

CLARK L. WILSON,
Vice President, Silver Buckle Mining Co.,
Wallace, Idaho.

DEAR MR. WILSON: Senator Anderson has forwarded to me your letter to him dated March 3, 1959, enclosing a copy of your letter dated February 28, 1959, to Mr. Jesse C. Johnson. In order to complete the record of your appearance before the Committee, we will plan to include both your March 3 and February 28 letters in the record after your testimony, unless you have any objection. If you do not approve of this idea, please let us know by March 18, 1959.

The Joint Committee was glad to receive your testimony during the section 202 hearings.

Sincerely yours,

JAMES T. RAMEY, *Executive Director.*

SILVER BUCKLE MINING CO.,
Wallace, Idaho, February 28, 1959.

JESSE C. JOHNSON,
Director, Division of Raw Materials,
U.S. Atomic Energy Commission, Washington, D.C.

DEAR MR. JOHNSON: As indicated in our telephone conversation of Friday, February 17, I am enclosing a copy of my remarks before the Joint Committee on Atomic Energy, with reference to production of uranium ore from the Peters lease on the Spokane Indian Reservation, State of Washington.

I would like to add some discussion of the Silver Buckle requests given on page 4 of my testimony. From your telephone comments, I realize that Silver Buckle is making requests countered to the present general AEC policy, but I would like to reemphasize that—

(1) We did enter a genuine application for mill contract that AEC refused—not on the individual merits of this project, but because of a change in policy.

(2) We were directed to use an existing mill on a custom basis. Because of our grade requirements and limited tonnage, this is not proving to be economically feasible.

(3) We rightly concluded that the AEC has direct responsibility in our situation and can and should make the adjustments to keep us in business.

Item (1) on page 4 is easily done, as your ore reserve estimates as of November 1958 will no doubt indicate the Silver Buckle deposit is the only substantial custom ore reserve.

The reasoning on item (2) is well covered in the remarks and was confirmed by your telephone comment that one reason Dawn is mining lower grade ore is because of an available custom ore supply of high-grade ore from Alaska. This confirms our argument that the custom miner is "high graded" to benefit the mill.

Item (3) can be handled three ways. Now that ore reserves are more or less "frozen," Silver Buckle should get a long-term contract on substantially all of the 100 tons per day custom capacity for the appropriate 335 days per year that the mill operates (33,500 tons). By increasing the Dawn tonnage and poundage, Buckle could have the advantage of the approximate 4 weeks per down time each year of 430 tons per day (11,200 tons). No doubt this mill can produce efficiently at 10 percent beyond rated capacity of 400 tons under present conditions and can add another 40 tons per day for Buckle ore (14,600). This would give us approximately 60,000 tons per year and would work our 424,000 ton reserve of 0.14 percent grade through the mill in 7 years (1965).

During our Washington visit of January 30, I handed you copies of correspondence on this matter, including my letter to Allen E. Jones of January 13. We would appreciate an answer to these requests and the ones given above so that our board of directors can determine whether or not Silver Buckle is going to be in the uranium business.

I believe it is agreed by you and us that this is a special situation primarily due to ore grades. We believe that under the particular circumstances our case deserves special handling.

Very truly yours,

CLARK L. WILSON, *Vice President.*

Chairman ANDERSON. The next witness is Mr. Spector.

STATEMENT BY DR. NORMAN A. SPECTOR, VICE PRESIDENT, VITRO CORP. OF AMERICA, NEW YORK, N.Y.

Mr. SPECTOR. Mr. Chairman and members of the Joint Committee, we appreciate the opportunity to be present at these hearings and to express our views on several aspects of the development, growth, and state of the atomic energy industry with which your committee is concerned.

Atomic power program: Appearing before your committee last year, we suggested that a new national program to achieve economic nuclear power should be geared to a time schedule of 10 years and the achievement of a 2 million electric kilowatts goal over this period.

We suggested further that the program focus on two classes of reactor size; these being 50,000 electric kilowatts and smaller, and 150,000 electric kilowatts and larger. We further recommended fuel development as a separate program and consideration of the following reactor concepts:

(1) natural uranium, (2) thorium uranium, (3) gas-cooled concepts.

We are gratified that progress has been made in many of these objectives and wish to present our recommendations of a policy that will in our opinion insure continued progress in achieving our goal.

It is appropriate to preface these remarks by stating our firm belief that it is the proper role of Government to encourage and assist in creating a nuclear power industry which it believes is necessary for domestic well-being and as an element of our international policy.

In achieving this objective we believe the Government should limit its activities to assist in bringing about the technical and economic climate in which such an industry will grow without becoming itself a part of that industry it seeks to foster. There is ample flexibility in such an approach without violating this basic philosophy, as our recommendations will demonstrate.

1. Power reactors—100 to 200 electrical megawatts.

(*a*) We recommend that the AEC not build any reactors in this size range, leaving the erection of such generating stations solely to industry. Industry would decide when, where, and the type of unit to be offered for construction.

(*b*) We suggest that AEC continue and expand research and development assistance to improve technology and economics of such units and that such assistance be provided directly to manufacturers of fuel and reactor components.

(*c*) We suggest consideration of a lump-sum dollar contribution by AEC to help defray increased costs of construction, possibly on a predetermined formula. This might be, for example, a fixed percentage of the excess capital cost over the conventional portion of a similar station.

(*d*) We further suggest that as an element of this phase of the program the Government define an objective of between 2 and 3 million electrical kilowatts over the next 9 years.

Chairman ANDERSON. Might I stop you there and say to you with reference to suggestion (*c*), that I made a comment in a talk not long ago that we might take the cost of a conventional plant and the cost of a nuclear plant and let the Government assume 75 to 90 percent of the difference.

I am not asking you to commit yourself to the wisdom of lack of wisdom of that proposal, but is that something of the type of thing you had in mind?

Mr. SPECTOR. This is exactly the type of thing that we might have in mind.

Chairman ANDERSON. Mr. McCone suggested the other day it might be 50 percent to the bus bar. I am not going to quarrel with those figures one way or the other, but I wanted to know if that is what you generally had in mind.

Mr. SPECTOR. It is, sir, and we feel it would clear the air.

This is generally the first phase of the program. We believe an equally important phase should concern itself with prototype reactors. I mean by this units which are prototypes and in the range of 30 to 50 electrical megawatts. I quite agree with the comments of Mr. Zinn that you can't define a prototype simply as being exactly of a given size. But generally, I believe we all can agree that they are within this range and not to be confused with large stations.

We think that AEC should assume full responsibility for this phase of the program and for the initiative in defining and executing an aggressive program of prototype construction.

We feel that certain prototype projects might be undertaken, where justified, in addition to the Government series but that this should not relieve the AEC of prime responsibility for defining and executing its own preferred program.

It should be the purpose of this program to learn and evaluate reactor concepts on an intermediate scale—more than can be learned from experiments alone and less than will be learned from production sized units.

It will be the result of this prototype program to give industry a common starting point on new reactor concepts from which the utilities working in their normal relationships with manufacturers, enineers, and constructors will undertake projects under the power reactor phase of this program.

We suggest the prototype program include projects for heat production and low-enrichment uranium-heavy water, thorium fuel, gas cooled, and breeder concepts.

We feel that the prototype program should define six projects for immediate consideration and be scheduled so that projects are started as soon as possible and none later than 5 years, under this program.

Chairman ANDERSON. May I interrupt you again there to say that the Joint Committee has a staff study and the Atomic Energy Commission has an ad hoc committee report that I think follows this to a degree. I am happy to have your comments on it.

I think this goes a little farther than the AEC ad hoc committee goes and I find myself in agreement with you on this subject, but nonetheless, I am glad to find that many of us are looking in the same direction.

Mr. SPECTOR. I find that very gratifying myself. I would like to emphasize for our part that in stating this prototype program it is our intention, to use a phrase, to put the monkey on the back of AEC. We think that here is an area that should be generally understood as theirs, and you do not come back and criticize industry and ask industry to do something.

Industry can supplement, but it is primarily the responsibility of AEC.

Chairman ANDERSON. It is a very heavy financial requirement that people who buy current cannot afford to pay.

Mr. SPECTOR. We recognize the major role which the National Laboratories have played in the development of most of the reactor concepts being considered today, and recommend that they continue in the national interest to enlarge the base of nuclear knowledge under this program.

We believe a policy of the type suggested will demonstrate clearly that we have a national program and a national objective, and one which is defined over a period of time long enough to permit both AEC and industry to do good planning. It has the advantage of focusing responsibility for the power program on industry and the prototype program on Government.

Thorium: There appears to be a current attitude that thorium fueled reactors are not to be seriously considered, perhaps because thorium supplies in the United States and the free world are not available in sufficient amounts. We are not able to obtain clarification on this aspect of reactor development policy and it is not our purpose to seek resolution of this point at these hearings.

However, the thorium reserves of the United States are substantial and on a global basis there is reason to believe that thorium is at least as abundant as uranium. There is also good reason to consider that production costs will be at least comparable to uranium and most probably, far less.

As a byproduct of certain uranium operations and from other normal sources of thorium there is already in being a capability to produce far more thorium than would be required for several years if an active thorium reactor program were to be undertaken immediately.

Given incentives for thorium exploration, mining and production similar to the raw materials program for uranium, it is probable that the results of private industry in this area would surpass even the magnificent achievement of the uranium industry.

If there is to be only a casual interest in the development of thorium reactors, let it be on the nuclear merits of the system—for to limit this program because the supply is limited is false reasoning.

Special nuclear materials: The development of advanced reactor concepts and at the moment particularly the program for nuclear propulsion of aircraft, has produced requirements for special nuclear materials like yttrium and europium. It is perhaps understandable that these programs being of a development nature have not found it possible to define firm specifications and firm requirements for supply of such special materials.

This has made it most difficult for industry to respond efficiently when spot requirements are announced and has prevented the orderly planning of production and commitment of capital funds. In addition the practice of permitting procurement of such materials from foreign sources has hampered the development of domestic production.

We strongly urge that more attention be given to the definition of requirements for such special materials and that procurement policies be put on a continuing basis instead of the spot purchase program currently employed by AEC. This will not only serve to create a healthy growth of domestic industry in these fields but will also have the effect of stabilizing availability and reducing prices.

It is also our desire to call to the attention of this committee the relationship between the availability of these important materials of the rare earth group and thorium supply. By processing monazite for the production of thorium substantial amounts of these rare earths are produced as byproducts—which of course, must be further refined

to meet AEC specifications. Accordingly, we urge the clarification of thorium and rare earth requirements coupled with a procurement policy designed to encourage the development of this domestic industry on an integrated basis.

Chairman ANDERSON. At the present time, when a miner brings in uranium ore that also has thorium in combination with it, he is not paid anything for the thorium, but it is just stacked off to the side.

Do you feel that there might be some consideration given to payment for this thorium?

Mr. SPECTOR. It is hard to say that there should not be consideration given to this thought, but I would find it difficult to believe that it would end up being a very significant factor for the reason that there are preferred thorium sources for thorium processing. On the other hand, I know of no significant area of this type in which thorium could be made available through simply the ore purchase process, since it would tend to show up largely as a byproduct from the processing.

You might find this more a factor with the milling industry rather than with the miners. I would certainly think this would help.

Chairman ANDERSON. Mr. Ramey?

Mr. RAMEY. Are you people engaged in a project with the Indian Government on heavy water?

Mr. SPECTOR. We are, sir, on heavy water production.

Mr. RAMEY. How is that program progressing?

Mr. SPECTOR. That program is substantially on schedule, which means it should be completed in approximately 1 year. This is a program to produce heavy water as a byproduct of ammonia production. It is relatively small production in terms of how we think of it today.

Mr. RAMEY. They are building a small heavy water reactor, are they?

Mr. SPECTOR. I understand that the heavy water will be used primarily to enable them to expand their research activity, but I think it tends to tie in with the fact that the Canadians have given the Indians an NRU reactor, which, as we all know is heavy water, and it is the direction in which the Indians are thinking.

I would also point out that being primarily a nation of vast thorium resources, I suspect this is also why they are thinking in this direction for a moderator.

Mr. RAMEY. You know the Joint Committee has been interested in the heavy water technology and have been considering it?

Mr. SPECTOR. I might add that like many others, who have perhaps appeared today, we have prepared our statements in advance. This is good planning, but some of the newer information that has come out in the last week has caught our statements out of date.

In view of the statements made before this committee, of our own recommendations, of the proposed program of the AEC, of the staff report of this committee, of the special report of the ad hoc committee to the AEC and of the proposed program of Mr. Gore, we have been impressed with the relatively large areas in which many people who are knowledgeable and interested in the development of

peaceful uses of atomic energy find substantial agreement. Many of us agree that—

(*a*) We must maintain unquestioned leadership in atomic power technology.

(*b*) We should strive to achieve economic atomic power at the earliest practicable date.

(*c*) We should accelerate the civilian atomic power program by setting a fixed kilowatt goal.

(*d*) We should concentrate on development of advanced reactor concepts by a prototype program.

There are many other areas of substantial agreement in matters of detailed program that I will not take the time to present.

Prime Minister Macmillan in his current visit to the Kremlin is quoted as follows:

There is so much that we can do together that I hope we might be able to concentrate on things that unite us rather than on things that divide us. At least let us not add to the burdens of mankind by becoming victims of our own propaganda.

I feel quite sure that the Prime Minister did not have in mind the progress of the peaceful atom when he voiced this hope.

I suggest, however, that this thought merits the consideration of all who are dedicated to the development and growth of the peaceful uses of atomic energy.

(Dr. Spector's supplementary statement follows:)

SUPPLEMENTARY STATEMENT BY DR. NORMAN A. SPECTOR, VICE PRESIDENT, VITRO CORP. OF AMERICA

In my discussion of the future role of thorium in reactor technology I had briefly mentioned the ready availability of thorium and the potentially large reserve of this fertile material. In order to put some quantitative numbers on the present known reserve of thorium, the following information is given:

Country	Known reserves of monazite (tons) [1]	Estimated percent of thorium oxide	Tons per thorium oxide
Australia	34,000	5	1,700
Brazil	300,000	5	15,000
Egypt	200,000	5	10,000
India	1,400,000	8	112,000
Formosa	8,700	5	435
Union of South Africa	200,000	5	10,000
Subtotal	2,142,700		149,135
United States:			
Bear Valley	244,000	5	12,200
North and South Carolina	126,000	5	6,300
Additional Southeastern United States	[2] 275,000	5	13,750
Total United States	645,000		32,250
Grand total	2,787,700		181,385

[1] Source: Paper presented to the February 1959 meeting of AIME by Dr. Anderson, Battelle Memorial Institute.
[2] Drilled by Heavy Minerals Co.

Additional domestic sources of monazite are known to exist in Wyoming, Montana, Idaho, North and South Carolina, Georgia, Alabama, Tennessee, but insufficient data are available to establish these occurrences as known reserves. Monazite is also known to occur in Ceylon, South Korea, Formosa, Malaya, Madagascar, Kenya, and Japan.

It should be emphasized that the above reserves have been developed without the intensive effort that have characterized the development of uranium supply. Much larger reserves could be anticipated should such an effort be undertaken.

Monazite is only one of several sources of thorium. Thorite (a thorium silicate mineral containing 20 to 60 percent thorium oxide) deposits are known to occur in several Western States, specifically, Colorado, Idaho, Montana, and New Mexico. Insufficient drilling has been done to determine a quantitative measure of these reserves but they are believed to be extensive.

Thorium is also produced as a byproduct of certain uranium operations. Of particular importance in this regard are the deposits in the Blind River area of Canada. Assuming a conservative uranium reserve of 400,000 tons in this area, a thorium reserve of 150,000 tons is indicated. This thorium could be produced as a byproduct of uranium production. Production of thorium oxide from this source, estimated at a level of 300,000 pounds per year, is anticipated to begin in 1959. Thorium is also produced by the Atomic Energy Commission of France as a byproduct of the processing of urano-thoride. Reserves are not known, but production is curently at a rate of approximately 300,000 pounds of thorium oxide per year.

In terms of present ability to produce thorium oxide, there is currently sufficient domestic processing plant capacity to produce 1,500,000 pounds of thorium oxide annually. Coupled with the very substantial production of thorium as a byproduct of uranium at the Blind River operation and the French AEC, this production is ample to satisfy any foreseeable demand for thorium. Indeed unless some expansion in market occurs the domestic thorium industry is faced with a serious situation of oversupply.

Chairman ANDERSON. Thank you very much.

This, then, completes the 202 hearings, except at a later date Mr. McCone, the Chairman of the Atomic Energy Commission may appear again and complete his statement.

Before we close, the staff has quite a number of statements for the record, and I will ask that they be included at this point.

(The statements referred to follow:)

AMERICAN POTASH & CHEMICAL CORP.,
Los Angeles, Calif., February 18, 1959.

Senator CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D.C.

DEAR SENATOR ANDERSON: Thank you for your letter dated January 27, 1959, to Mr. Charles R. Lindsay III, president of our Lindsay Chemical Division, extending an invitation to testify or submit a statement for the record in connection with your forthcoming section 202 hearings.

We are pleased to submit a brief statement on the Nation's atomic energy program as it affects those in the thorium-producing industry. Recently, we embarked on a comprehensive study and analysis of fuel cycles and expect to report our conclusions shortly. This study was initiated as the result of the emphasis placed on uranium as opposed to thorium in the Government reactor program in spite of the great potential value of thorium as a fertile material.

The preliminary results of our study disclose the following:

A. On a technical level, we have found there are many scientists and engineers in both government and industry who prefer the use of thorium to uranium 238 as a fertile material.

B. It appears that industry is more actively pursuing development of the thorium cycle than is the AEC. This is a striking circumstance in view of the fact that a premium has been placed on the production of plutonium through guaranteed fuel prices.

We have noted some statements of concern with the thorium reserves available to support and sustain reactors using the thorium cycle. We wish to point out that the ratio of proven economical thorium reserves to annual thorium consumption is approximately 5,000 to 1 on a worldwide basis, and even higher domestically. Furthermore, the energy which may be derived from the proven economical thorium reserves is equivalent to approximately five times that recoverable from fossil fuels and enough to supply the world's energy needs at the present rate for approximately 300 years. Even in the absence of incentives

to explore for additional thorium deposits, there is a supply on hand which makes it a major source of energy by any standards. As in the case of uranium and other minerals which were scarce at one time, it is reasonable to expect that as the demand for thorium increases, large additional deposits will be discovered. A comparison between the present reserves of uranium and thorium is not reasonable because of the incentives placed on the discovery of uranium while no such incentives are provided for discovery of additional thorium, since it is presently in adequate supply.

The available information leads us to the conclusion that thorium is a superior fertile material for thermal reactors. We are planning to present the study, when completed, to the AEC, together with our suggestions for future programs. Until this is done, we ask that fuel cycle programs, such as plutonium recycle, be left sufficiently flexible to permit inclusion of the thorium cycle.

We wish to thank you sincerely for giving us this opportunity to present our views.

Very truly yours,

G. S. WHEATON, *Vice President.*

STATEMENT BY DR. CHAUNCEY STARR, GENERAL MANAGER, ATOMICS INTERNATIONAL DIVISION, AND VICE PRESIDENT, NORTH AMERICAN AVIATION, INC.

Among the most important developments in the atomic energy field this past year has been the concerted effort, by both the Atomic Energy Commission and this Committee, to arrive at a balanced logical program for the advancement of the technology. It may be of some value to consider some of the fundamental difficulties which are constantly present in a field as new as atomic energy.

We know that the development of any technology requires the simultaneous performance of three types of programs: First, fundamental feasibility research in crucial key areas of scientific ignorance; second, the experimental development both on a laboratory and engineering scale of new concepts; and third, the large-scale demonstration, operation, and improvement of prototype devices. The first program, fundamental research, eestablishes the basic feasibility of concepts, i.e., it separates the possible from the impossible. The second program establishes the practicality of a concept, i.e., it shows that the concept can be made to work with reasonably available devices and at reasonable costs. The third program establishes the suitability of the concept for incorporation into the productive machinery of our society, i.e., it proves the economic desirability of utilizing the concept on a full scale.

As a result of the creative ability of engineers and scientists, new and improved concepts are continuously being generated, and, since some of these new ideas may significantly improve the technology, they are frequently supported through all three of the programs described above. Consequently, in any healthy environment, the full-scale devices are technologically obsolete with respect to those in the experimental stages, and they in turn are obsolete relative to those in the feasibility stage.

A judicious balance of effort must be maintained in all three types of endeavors to insure a sound technological development. Such balance usually results from the free play of commercial and industrial interests. In the field of atomic energy, however, where one Government agency controls the destiny of all phases of the work, it is particularly easy for the program to become the victim of the oversimplified "perfect solution." The "perfect solution" objective is often evidenced on the technical side in a desire to delay construction of reactor prototypes today because it will be possible to design better plants at some later date. It has been evident for some time that prototype construction is vital to the growth of the technology, and is necessary for the most rapid achievement of our goals. Although I would agree that a judicious choice of type and timing must be made, a positive program for prototype reactor construction must be maintained, even though improved concepts are on the way.

Other examples of the "perfect solution" attitude can be found in two recent reactor program suggestions—one, the idea of concentrating all national effort on a single existent type, and the other the thesis that the long-range breeder concept is the only worthwhile effort. The first viewpoint was that of the so-called hardheaded businessman, and the second that of the academic purist. They would balance each other nicely if only they were promulgated with equal vigor and at the same time. I am pleased to note that the AEC's statements before this Committee describe a program which avoided these extremes.

It is worth while to explore a little more deeply the doctrine that since the most efficient way to utilize our uranium supplies is through breeding, we should abandon other reactor approaches and wait until breeders are economical before we seriously attempt to develop nuclear power. "Breeding" is a misleading term that describes a reactor which achieves a conversion ratio of 1 or more. This means that for every atom of fissionable material burned in a reactor, another atom of fissionable material is created. Today's thermal reactors have conversion ratios in the neighborhood of 0.7, which simply means that if we burn 10 atoms of uranium, we get bock only 7 atoms of plutonium, while in a breeder we would achieve a rate of 10 or more atoms of plutonium for each 10 atoms of uranium burned. There is no doubt that it is theoretically quite feasible to construct reactors with conversion ratios of 1 or more, but it turns out that they are difficult and expensive to build. If our whole reactor development program is held back until it is possible to build breeder reactors that are sufficiently economic, I do not expect to see competitive nuclear power in the United States for many decades.

It is easy to recall that 40 years ago fossil-fueled powerplants had efficiencies of about 10 percent. It might have appeared quite logical to decide that no more plants would be built until efficiencies of 30 or 35 percent had been achieved. After all, our fossil fuels are limited and it can be argued that to burn valuable coal and oil at anything but a high efficiency is wasteful and against proper public policy. While such a policy would have saved money and conserved fossil fuels, it is quite likely that we would still be using kerosene lamps, candles, and gas for artificial light.

So far, I have been talking about the "perfect solution" principally as it affects the technical problems in atomic energy development, but the same difficulties have equally affected policy and administrative considerations.

I recall the dual-purpose reactor program that was proposed several years ago. There were many valid and logical arguments against such a program, the need for additional plutonium was not clear; there was fear that plants would be optimized for plutonium production rather than power and that a distortion of the technology would result; and it was finally argued that if more plutonium were required, the most economical way to produce it was through construction of more Hanford reactors. With the advantage of hindsight, however, it is possible to see that had the dual-purpose program been adopted, we might now have 10 or more full-scale nuclear powerplants operating in the United States. It is also probable that our plutonium production would be at a level which would make it unnecessary for the Government to spend $145 million for new production facilities at Hanford. The dual-purpose program was not the "perfect solution," but it certainly would have hastened us toward our goal of economic power. The British, of course, have successfully adopted the dual-purpose approach in their Calder Hall reactors.

While the dual purpose program was rejected on the basis of very valid arguments—incidentally, arguments with which I agreed—from the present vantage point in time, I regard it as a lost opportunity. I believe we now have another opportunity to undertake a program which will result in a rapid acceleration of our nuclear power program and I hope that we do not make the mistake of rejecting it because it fails to meet the "perfect solution" criterion. I refer to the proposal of capital cost assistance for construction of nuclear powerplants through Government grants to utility operators. Government grant proposals have been put forward by Senator Anderson, the chairman of this committee, and independently by Mr. Willis Gale of the Commonwealth Edison Co. At the time, there was very little reaction from the industry. But it appears that in the intervening months, opinion has solidified and that a majority of those who are concerned with doing something about the nuclear program now believe that a system of grants is an acceptable, if imperfect, solution to the problem. I was most impressed by the fact that so many of those who commented on the Joint Committee's proposed nuclear program statement favored such assistance for utility systems.

The logic of Government grants for construction of nuclear plants is extremely simple. There is agreement that a sensible nuclear power program will involve construction costs on the order of $500 million during the next 10 years. Without a system of Government grants, most of this expenditure is likely to come from the Federal budget. If the grant system is adopted, more than half of this cost will come from utility systems and the Federal taxpayer will realize a savings of many millions of dollars. In effect, the Government will achieve

its end purpose—which is the development of technical and economic data—at substantially less cost.

I suggest there is another equally important reason for such a program and it goes back to the dual purpose reactors that I mentioned previously. Utility systems receiving Federal grants for construction of powerplants certainly would agree that in time of national emergency they would operate these plants on a shortened fuel cycle to provide an emergency supply of plutonium. In addition to meeting the urgent national objective of developing economic nuclear power, we can provide against the future possibility that our current planning for plutonium production is inadequate.

One of the problems often mentioned as a stumbling block in implementing such a Government grant program has been a suggestion that it would be necessary for the Federal Government to take title to portions of plants constructed with Federal funds. I see no reason why this should be so. As I mentioned earlier, the Government is getting technical and economic construction and operating information at approximately half the investment it would otherwise make. Private and public utilities participating in such a program are not receiving a windfall, since the plants constructed would not produce power cheaper than current conventional plants. Under these circumstances, it would serve no public need to have the Federal Government maintain strings which are quite properly unacceptable to the largest segment of our power industry. There is also no precedent in other Government support programs for taking a lien or retaining title simply because Federal moneys have been made available to benefit particular industries. I have in mind the programs for support of such activities as railroads, airlines, and agriculture.

Like any other technical or administrative plan, the system of Government grants is not a "perfect solution." It does, however, offer the best opportunity currently available to do something really significant in accelerating our nuclear power program. There appears to be very close agreement on what kind and how many atomic powerplants we should build. We have at hand a plan for constructing these plants partially at Government expense, partially at the expense of the utility systems. This is a sensible program we can get on with.

STATEMENT OF THE BABCOCK & WILCOX CO.

The Babcock & Wilcox Co. is pleased to have this opportunity to submit comments during the 202 hearings, particularly with respect to the Joint Committee's staff report and the Atomic Energy Commission's ad hoc committee report.

The investigations and evaluations by the Joint Committee on Atomic Energy of the progress and the long range objectives of the United States in the reactor field are indeed heartening in that they show a determination that the United States shall maintain a position of leadership in the reactor field. This keeps before us the long range objectives, as we continue to build the best reactors which can be built in the meanwhile.

We note with interest in the report of the ad hoc committee their reference to the list of reactors worthy of consideration as prepared by the Joint Committee on Atomic Energy, the Atomic Energy Commission and the Edison Electric Institute. It is gratifying to note the committee's statement that the views of the JCAE, the AEC, and EEI and the ad hoc committee in regard to these reactor types appear generally consistent. It is important that there appears to be a determination to set up a national reactor program and general agreement as to the base upon which it is to be built.

The concise list of important technical factors in the ad hoc committee's report shows an unusually excellent comprehension of the technical problem, and introduces a very fine discussion of the complex interaction of these factors.

We agree with the ad hoc committee that the water reactors have come of age to the extent that the building of the large size water reactors should be left from now on to industry. It will be helpful if contracts can be worked out to build a few of these reactors in connection with the Euratom program. We agree that it will also be helpful if the Government finances the obtaining of certain basic data, such as the determination of "eta" for U^{233}.

In the important area of ship propulsion, the reactor capacities required for ships of practical sizes are smaller than for the larger central station reactors which offer economic power in Europe today and the still larger ones which should shortly provide economic power in certain areas of the United States.

Although many factors are involved, it appears that the size factor is such that substantial design improvements will be required before atomic power is economically competitive on most merchant ships.

It is an accepted fact that our merchant marine and shipping industry have a national importance which transcends a purely economic consideration. Therefore, development of new equipment for the merchant marine is important to the Nation.

Nuclear powerplants offer certain advantages for merchant ships. Among these is the saving in the quantity and weight of fuel that must be carried. This saving in fuel means more cargo carrying capacity per ship, with the resulting reduction in the total number of ships required. In time of an emergency, this would represent a large saving in material and labor. In ordinary times, it could result in more economical operation. If high speed is desired, these advantages should be greater in degree since the great increase in fuel storage space required for increased speed in a conventional plant is not needed in a nuclear plant.

Since the achievement of economical nuclear power for ships depends on development work, it is important that a carefully worked out program be prepared, so that actual operating experience can be obtained and evaluated as a basis for future design.

We are pleased to be able to report that the propulsion equipment for the NS *Savannah* is in all essential respects on schedule. The delivery of equipment to the shipyard has begun, and most of the heavy items of steam generating and propulsion equipment will be delivered between now and April. With the operation of the *Savannah* in 1960, the Nation will begin to accumulate operating experience and information which are a necessary part of the evaluation of a nuclear maritime program.

Within the past year the Babcock & Wilcox Co. has been conducting design and development work at its own expense, some of which is being applied to an improved merchant ship reactor. It is our opinion that additional merchant ships with powerplants based upon improved designs should be built as the next step toward economic plants. In these plants economy can be improved without sacrificing reliability and those safety requirements which all of us feel must be provided. For a number of reasons certain types of vessels such as tankers and icebreakers appear to be particularly suitable for application of nuclear power.

With the thought that you may be interested in a brief appraisal of the atomic energy operations of the Babcock & Wilcox Co. during the past year, I will mention progress in some technical and manufacturing areas.

The Indian Point reactor, which we are designing, developing, and fabricating for the Consolidated Edison Co. of New York, will be reported upon by Mr. Fairman of the Consolidated Edison Co.

We are continuing the design and development of a liquid metal fuel reactor experiment under the contract which we have with the AEC. This concept, based on liquid bismuth cooling, is one of three fluid fuel reactors currently being evaluated by the AEC. On the basis of our findings we agree with the ad hoc committee that this reactor concept may have the three advantages of a simplified fuel cycle, a capability of operation at high temperature, and a thermal breeder. We feel that this concept is of sufficient promise that work should be continued on it as long as the technical problems are continuing to yield to solution.

We have fabricated and delivered to a number of customers, including the Government, a variety of components, including pressure vessels, steam generators, and fuel elements. In the fabrication of this equipment we have improved our manufacturing techniques and our knowledge of manufacturing costs.

We are not yet making a profit in atomic energy. On the contrary we are still sustaining substantial operating losses while continuing to make substantial capital investments.

The AEC's contract policy in the reactor development field has been included as one of the suggested topics for comment. We value the opportunity to work on reactor development contracts, and appreciate the opportunities which the Government through the AEC is giving to industry in this area, including the Euratom program. However, the patent provisions which the Government seeks to include in these contracts are a source of difficulty in negotiations. This is mainly due to the lack of any patent rights for the contractor in the atomic energy field under AEC research and development contracts, the inclusion of

patent rights clauses in fixed price equipment contracts, and the effect of the broad language of section 152 on concurrent work of the contractor at his own expense in the atomic energy field.

Another area of concern is the method for determining costs on cost type contracts. Due to the fact that many expenses which must be incurred in the execution of these contracts are considered as unallowable by the Government, it is not possible to recover the full cost of doing the work.

In conclusion, we wish to state our appreciation of the amount of time and effort which the Joint Committee on Atomic Energy is devoting to the establishment and improvement of our national atomic energy program, and also to express our appreciation of this opportunity to present our views.

BLAW-KNOX CO.,
Pittsburgh, Pa., February 10, 1959.

GEORGE F. MURPHY, Jr.,
U.S. Capitol Building,
Washington, D.C.

DEAR MR. MURPHY: We appreciate receiving the January 27 letter from the Honorable Clinton P. Anderson, Senator from the State of New Mexico, inviting us to participate in the public hearings by the Joint Committee on Atomic Energy. My absence from the city has prevented my answering earlier.

In our letter of October 28, 1958, which has been published in the report of the Joint Committee, certain views of the Blaw-Knox Co. were submitted for the record. Since we have nothing particular to add at this time, we do not desire to testify at these hearings.

However, we would like to submit these comments on the first topic on atomic power. The Commission's ad hoc committee report and the Joint Committee staff report provide conclusive evidence that through positive but flexible direction by the Atomic Energy Commission, the United States can meet the specified objectives. A published policy of ground rules which assure "give and take" cooperation between Government and industry is mandatory to overcoming primary bottlenecks caused by the lack of profit potential in these early stages of nuclear development. A substantial contribution to our international security can also be realized if this country's program to develop peaceful uses of atomic energy is pursued as vigorously as its military counterpart.

Sincerely yours,

W. CORDES SNYDER, Jr.,
Chairman and President.

BURNS & ROE, INC.,
New York, N.Y., February 16, 1959.

Hon. CLINTON P. ANDERSON,
Congress of the United States,
Joint Committee on Atomic Energy,
Washington, D.C.

MY DEAR SENATOR ANDERSON: We appreciate the opportunity afforded us to comment on the development, growth, and state of the atomic energy industry. Since Burns & Roe, Inc., has been particularly active in this area for a number of years, we appreciate this opportunity and hope that our comments will contribute to the development of a strong and dynamic nuclear industry.

Our comments on the Euratom program and the proposed expanded nuclear reactor program are on file with your staff. We recently had the opportunity to review the ad hoc advisory committee report to the Atomic Energy Commission on reactor policies and programs. Our comments are primarily concerned with the reactor power policies in the list of suggested topics that you have enclosed.

The Euratom proposal, the ad hoc and Joint Committee reports all emphasize the need for further development on improved fuel cycles in order to better define and to reduce the cost of fuel fabrication and reprocessing for the heterogeneous reactors. This development is indeed essential if nuclear power produced by heterogeneous reactors is to be competitive with conventional fossil fuel plants.

There are three points in the development of heterogeneous reactors that, in our opinion, need more intensive consideration:

1. The development of superheaters operating on atomic heat.

2. Further development to lower the cost of reactor designs and heat exchangers by standardization and substitution of lower cost materials for the very expensive stainless steels and similar materials now used. This development must be coupled, of course, with means to use these materials without increasing safety hazards.

3. Methods looking toward the gradual and orderly reduction of fuel costs in order to make atomic fuel more competitive with fossil fuels.

As important as it is to continue the development of heterogeneous reactors which would be competitive with conventional fossil fuel plants, we must not overlook the important fact that homogeneous reactors inherently offer just such a means of reducing fuel cycle costs because of the elimination of the need for fabrication and the inherent simplicity in reprocessing. There is an apparent reduction as indicated by the ad hoc committee report on the research and development effort on homogeneous reactors. This policy results from the fact that heterogeneous reactors have been developed quite successfully, whereas the development of the homogeneous types has moved slowly because of problems involved, including that of corrosion. The possibility of low fuel costs by the homogeneous reactor types is far greater than for the heterogeneous. Therefore, it would indeed be unfortunate if our homogeneous reactor development is deemphasized as indicated by the ad hoc committee report. The need for a low fuel cycle cost should encourage expanded development on the homogeneous reactor types.

We recognize that the homogeneous reactor presents many problems which have considerable distance to go before they are solved. While it is easy to take the path of least resistance and develop the type of reactor with the least problems, we believe in this intsance the fundamental advantages which appear inherent to the homogeneous reactor warrant further work and study on this type.

Although the pressurized water and boiling-water-type reactors have reached the point where private industry undoubtedly would participate in their further development, it is clear that private industry will only do so to the extent that they can see some possible future return for their investment and we believe that a certain amount of Government help will still be necessary in this field.

In the development of homogeneous reactors, gas-cooled reactors and liquid metal high-temperature reactors, the basic research for these will largely have to be carried on by the Government or with Government aid if their competitiveness is to be determined at an early date. Therefore, we would recommend a review of the security needs on the data acquired on the multi-million-dollar expenditures which have already been carried out in the aircraft nuclear propulsion program, plutonium production program and Army mobile program. It is entirely possible that much of the technical information developed in these programs, if it could be released either on a broad classified basis or otherwise, would be helpful in the further development of suitable use of these concepts. We recognize fully that this information can only be released to the extent that it does not jeopardize national security, but we feel that it may be released safely within the framework of the existing access permit procedure.

It is our understanding that one of the reasons for undertaking the joint Euratom-AEC agreement was to encourage the construction of American-type reactor plants in areas where economic nuclear power seemed possible and thereby stimulate the nuclear business for the U.S. manufacturers. The U.S. utilities have always considered it necessary to have an engineering organization evaluate and design their plants before purchasing any equipment, in order to come up with the most economic plant for their specific requirements. This procedure has proven itself through many years of conventional plant design as well as in recent years in nuclear power design. There is nothing in the Euratom-AEC agreement that encourages or specifies the need for an engineering organization to do the complete plant design, but rather looks to the reactor manufacturers to offer a complete powerplant. We believe it is better and sounder practice to divorce overall plant engineering from the manufacture of essential equipment and that this overall plant engineering should be handled by engineering organizations in the conventional way.

In recent years the AEC has sought ways and means of encouraging the chemical industry to design and build reprocessing plants for the civilian reactors. To date it has not been commercially feasible for private industry to engage in these operations. Until fuels are better standardized or until a continuing adequate volume of fuel is produced for further processing, it is not expected that industry will invest in processing plants which might become ob-

solete at the time of their completion. The AEC will have to continue to reprocess reactor fuels until a time has been reached in which there is a chance for a reasonable return on a very large investment. It may be 10 years before the nuclear industry creates a large enough demand for such reprocessing, and probably another 5 years before any particular method of processing can be proven to look economical under operating conditions. It is possible, therefore, that the AEC installations will have to continue this service for another 15 years.

It is a general practice by the AEC to evaluate any new reactor concepts before proceeding with further development of this type. These evaluations are usually in the form of economic comparisons of one nuclear type with other nuclear types or with conventional powerplants. No one can disagree with the need for such evaluations in order to develop the basic data on the cost of power by a certain reactor type. We have carried out such studies and look forward to continuing to do so in the future. However, it is apparent to us in reviewing some of our own studies and studies made by others, that we must be very careful in our basic assumptions in order not to be misled or to mislead others as to the acceptance or rejection of reactor types for further consideration. Whereas in the power industry we have some 50 years' experience to base our assumptions on, in the reactor industry our experience is limited and, therefore, the assumptions must be weighed very much more carefully to be sure of their validity, as an incorrect assumption may change the whole concept of the reactor being studied.

To illustrate this point, the availability of a development reactor should not be taken as the criterion for the availability of the same type of reactor when used for power. It is possible that the development reactor would be overdesigned and, therefore, some sober, careful evaluation should be given to improving designed power reactors by reducing their cost without jeopardizing their reliability and safety. Another fallacy we have recently noted is the comparison of costs from reactors with fossil fuels on a present-day basis. Historically, fossil fuels have increased in price over the years at a fairly uniform rate whereas nuclear fuels are expected to decrease in cost as nuclear developments permit use of lower grade fuels or cheaper fuels. Therefore, basing the economics of nuclear plants solely on present-day fuel cost is not totally realistic.

We should also bear in mind that in general we are still in a development stage of nuclear powerplants and some consideration must be given to the advancement of the art as well as to the economics although it is quite clear that from a longrun viewpoint economics will have to govern. But the best economics can be produced only if the development of the technology necessary to acquire these economics is also encouraged.

The ad hoc committee does not consider it necessary for the Government to finance large (200 mw.) nuclear plants if utilities do not subscribe to such construction. The incentive for utilities to build such large plants would not be great if the prospects of producing economic power are not promising. The ad hoc committee, however, recommends 80-mw. prototypes be built by the Govovernment or utilities rather than the larger size. With all the uncertainties that still exist regarding nuclear power costs, we feel that an 80-mw. would be just as suitable as a 200-mw. plant for demonstrating economic feasibility of any specific type. This degree of difference due to size is a small order of magnitude compared to the many other factors enumerated above.

With regard to administrative and organizational problems, we feel that the establishment of national objectives will contribute largely to the proper solution of difficulties in this area. We are greatly encouraged by the determination of both the Joint Committee and the AEC to set these objectives, and we look forward to an enthusiastic and coordinated effort by the Government and private enterprise in the development of a strong and dynamic nuclear industry.

We hope these comments will be of help to your committee. If we can be of further service in assisting the Joint Committee to formulate a strong atomic energy program, we would be more than pleased to do so at your convenience.

Sincerely yours,

R. C. ROE, *President.*

STATEMENT BY CAROLINAS VIRGINIA NUCLEAR POWER ASSOCIATES

The Carolinas Virginia Nuclear Power Associates, a nonprofit corporation, organized under the laws of the State of North Carolina on October 4, 1956, is composed of four privately owned utilities; namely, Carolina Power & Light Co., with headquarters at Raleigh, N.C.; Duke Power Co., with headquarters at Charlotte, N.C.; South Carolina Electric & Gas Co., with headquarters at Columbia, S.C.; and Virginia Electric & Power Co., with headquarters at Richmond, Va. Jointly, they serve most of the area of Virginia, North Carolina, and South Carolina. Their electric customers approximate 2,300,000.

The four companies, interested in research and development as well as the future potential of atomic energy for peacetime use in the economic generation of electricity, formed a nonprofit corporation to respond to the invitation of the Joint Congressional Committee on Atomic Energy to construct a prototype atomic energy plant that would contribute to the technical art of utilizing atomic energy to generate steam and, in turn, produce electricity.

After a series of conferences with the staff of the Atomic Energy Commission and with the assistance of nuclear consultants, it was mutually agreed that the Carolinas Virginia Nuclear Power Associates would undertake a research and development project which would utilize the principle of a heavy water, moderated and cooled, slightly enriched uranium, pressurized tube theory.

To carry out the program, the services of Stone & Webster Engineering Corp., Westinghouse Electric Corp., and General Nuclear Engineering Corp. were secured.

CVNPA wishes to advise the Joint Congressional Committee on Atomic Energy of its progress to date.

After the action of the committee, the first necessary step was to finalize the prime contract between the Atomic Energy Commission and Carolinas Virginia Nuclear Power Associates, together with a guarantee agreement called research and experimental agreement by each of the four sponsoring utilities; namely, Carolina Power & Light Co., Duke Power Co., South Carolina Electric & Gas Co., and Virginia Electric & Power Co., as well as Carolinas Virginia Nuclear Power Associates.

The negotiations for the final approval of all these parties were completed as rapidly as possible. The guarantee agreement was signed on January 9, 1959. The prime contact with AEC was signed on January 12, 1959. Immediately thereupon we undertook active negotiations with the Commission and with Westinghouse Electric Corp. for the development of a final agreed text for the research and development subcontract between Westinghouse and CVNPA. Conferences on the terms of this contract were held with Westinghouse on February 10 and with the Commission on February 11–12. On some points that were reserved during the course of the discussions, active consideration is still proceeding and we expect that the agreement will be put in final form and signed at an early date.

At that time any necessary conforming changes can be made in the two other existing subcontracts, with General Nuclear Engineering Corp. as consultants and with Stone & Webster Engineering Corp. as independent engineers. The only other contracts needed at the present time, both with South Carolina Electric & Gas Co., one for the lease of the reactor site and the other for the purchase of the steam produced, are on the verge of execution.

In order to maintain the progress of the work on schedule, we have not delayed the commencement of the research and development work until the execution of the Westinghouse contract. Its work is actively underway at the present time. In addition the meteorological testing devices have been installed at the plant site and observations are being currently made in accordance with the requirements of the Commission.

In addition we have held a coordination conference with the staff of the New York Operations Office of the Commission to whom the administration of the contract has been assigned.

We are happy therefore to assure the committee that the work in all theaters is progressing actively and in accordance with schedule. If there is any further information you would like, it will be a pleasure to advise you.

CVNPA wishes to acknowledge the help, assistance, and cooperation given by AEC and its staff and the approval of the AEC contract given by the Joint Congressional Committee on Atomic Energy.

CHAMBER OF COMMERCE OF THE UNITED STATES OF AMERICA—POLICY ON ATOMIC ENERGY

ATOMIC ENERGY INDUSTRY

The advancement of a sound and progressive atomic industry is important to the economic growth and the welfare and security of the United States.

The rate of progress in the United States toward development of an atomic industry has been substantial. This progress has enabled our country to attain a position of international leadership in the development of commercial uses of atomic energy. The chamber recognizes that this position is valuable, that it could be lost, and that some domestic activities must be keyed to maintaining this leadership.

It is essential that all interests and agencies engaged in this development use the forces of private enterprise through initiative and competition.

INFORMATION

Both industry and Government must further the widest possible public knowledge and understanding of the uses of the atom. Continuing efforts should be made toward the end of having information pertinent to industrial atomic energy developments originate and remain unclassified.

Whenever classified military information is developed which is applicable to the civilian program it should be possible to obtain full access to this information by meeting the requirements of an appropriate security clearance procedure. The present program of rapid declassification should be continued.

LICENSES AND REGULATIONS

Since licensing is restrictive and regulating is permissive of private enterprise and competition—

1. licenses and materials should be granted by the Atomic Energy Commission on a broad, rather than specific, basis; and,
2. progress should be made toward eliminating licensing in favor of regulatory criteria established by due process.

PATENTS

To assure maximum utilization of individual creative ability, normal patent rights (as established by the patent statutes of the United States) should be applied to all inventions relating to atomic energy for both civilian and military purposes.

Pending restoration of normal patent rights, American industry should be permitted to obtain adequate patent protection in foreign countries. For this purpose, Government contractual relationships should permit private contractors to take the initiative in establishing appropriate foreign patent rights in their inventions.

INTERNATIONAL ATOMIC ENERGY AGENCY

To the extent the International Atomic Energy Agency encourages a spirit of cooperation and mutual trust and promotes removal of restrictions and the establishment of normal trade relations in this field it can make a substantial contribution toward peaceful progress for mankind and reduce international tensions. The extent of continued support should be based on a realistic appraisal of the accomplishments of the Agency.

INTERNATIONAL ATOMIC ENERGY AGREEMENTS

All international agreements should provide that information exchanged under such agreements be fully available to U.S. citizens on the basis of their meeting the requirements of appropriate security clearance procedures and should encourage free enterprise trade relations. For the present, bilateral agreements offer considerable promise for immediate accomplishments.

FEDERAL-STATE RELATIONSHIPS

The traditional pattern of Federal-State and industry cooperation in developing standards for the regulation and licensing of private business ventures has not evolved in the atomic energy field. However, more and more States are

properly exercising their jurisdiction in this area. Uniformity in the regulations of the various States covering conditions of health and safety is imperative, however, if the civilian atomic energy industry is to continue to grow. Toward this end, the Atomic Energy Commission and all the States should cooperate to assure proper understanding of the needs.

Uniform national, State, and other governmental regulations, should be developed in cooperation with the American Standards Association and other nationally recognized organizations of like purpose thus assuring the participation of industry and other interested groups.

FEDERAL INDEMNITY FOR ATOMIC INSTALLATIONS

The chamber's policy adopted in 1957 was as follows:

"The Federal Government should undertake to indemnify private manufacturers, operators, and others engaged in atomic activity for liabilities to third parties incurred in excess of the amount covered by private insurance, resulting from an atomic facility incident. Such indemnification should only be available for amounts in excess of amounts of insurance required by the Atomic Energy Commission based on its evaluation of the hazards involved. If the amount of private insurance available from year to year is less than the amount required by the Atomic Energy Commission, the indemnification should take effect at that point.

"To its maximum capacity, except as provided in the preceding two sentences, private insurance should be utilized in providing coverage of the liability of reactor operators and suppliers of component parts and, within such capacity, Government indemnification or intervention is opposed.

"The Government's participation should avoid duplication of services and agencies; therefore, the Atomic Energy Commission should administer the Government's program. The Commission should be empowered within legislative standards stated as explicitly as possible under the circumstances to negotiate for, and utilize fully, on the basis of reasonable cost, the services and facilities of the insurance industry in the issuance of agreements and the investigation and settlement of claims."

Effectiveness of the Federal Atomic Indemnity Administrative Act of 1957 depends upon definitive administrative rulings consistent with the above policy.

ATOMIC ELECTRIC POWER

The primary objective of atomic power development activities in this country has been and should continue to be the achievement of a safe, economically competitive means for producing electricity from atomic energy. Because of this Nation's large supplies of relatively inexpensive fossil fuels and its advanced electric power technology, the full achievement of this objective will require the solution of formidable economic and technical problems.

Progress thus far in atomic power development indicates that new technology and knowledge are necessary before practical, economically competitive atomic power can become a reality in most parts of this country. Such information can be obtained only through continued intensive research, supplemented by the construction of pilot and prototype plants and of large-scale reactors. The latter should not be attempted unless justified by the status of technology developed through prior research efforts.

In view of the fortunate fossil fuel situation in the United States, the scope and rate of progress of domestic atomic power development is both substantial and adequate from the standpoint of meeting this Nation's energy needs. Since late 1954, when Government monopoly of atomic power development was lifted, industry has independently financed and constructed notable atomic research and developmental facilities, and has undertaken atomic powerplant construction projects which involve a wide variety of reactor concepts. These trends are continuing. Anticipating and supplying domestic requirements is the proper role and obligation of industry. This role should be strongly encouraged as national policy.

Matters of policy and the position of the U.S. Government with respect to other nations should be continuously examined to determine how they influence the rate of progress, scope, or other aspects of atomic power development activities in this country. Any activity undertaken or new policies adopted because of international considerations should also be with full regard for the effect on this Nation's free enterprise system.

The following principles should be adhered to in carrying out atomic power development activities in the United States:

1. Policies and programs should be designed to make maximum use of the Nation's free enterprise system. Faster progress will be made through reliance upon the strength of the Nation's industrial system rather than through Government ownership, direction or control. Government controls and Government regulations of any aspects of atomic power development should not go further than required to fulfill soundly conceived and clearly defined national objectives. Such controls and regulation should be directed, as stated in the Atomic Energy Act of 1954, "so as to * * * strengthen free competition in private enterprise."

2. The effects of Government-supported programs should be periodically assayed by both the Government and industry with a view toward their broad goals as well as their effect on already existing industries.

3. The Federal Government should not own or operate atomic powerplants for commercial energy production. Aside from regulation, Government activity in the area of atomic power generation should be limited to research, development, experimentation, and the encouragement of wide industrial participation. As soon as the stated purpose of any Government experimental facility has been achieved, it should be disposed of. Should any Government experimental facility have a residual economically feasible use, it should be offered for sale. The production for sale to the public of electricity generated by means of atomic power should be the responsibility of the existing utility industry. Any interim production of atomic energy by experimental facilities at Federal Government atomic energy installations should either be used by the Government in the operation of such installations or disposed of on a nonexclusive basis to distributing utilities in the area without preference or discrimination.

4. To the extent possible, without endangering national security, the Government should make public all information as to the full amount of any Federal financial assistance requested or spent in the research, development, construction and/or operation of any commercial atomic power program in which it participates.

RAW MATERIALS

The development of extensive uranium ore reserves and rapidly growing producing capacity in the United States for other materials peculiar to the nuclear industry is further evidence of private enterprise ability to fullfill our national and international responsibilities. It is important that a proper balance be provided between reserves, producing capacity, and the utilization of such materials in both the civilian and military programs.

During the period when the U.S. Government is the principal or sole customer, it has the obligation to provide all its available information which industry requires to plan its future.

CITIES SERVICE OIL CO.,
New York, N.Y., February 13, 1959.

Hon. CLINTON P. ANDERSON,
U.S. Senate, Washington, D.C.

DEAR SIR: This will acknowledge your letter of January 27, inviting me to testify before the Joint Committee on Atomic Energy. The only subject listed on page 2 of your letter on which I feel qualified to comment is item (3), namely, the Government's program for nuclear maritime propulsion. As I shall be in Europe on the dates you mention for the hearings, I thought it best to reply to you by letter.

Over the past 3 years, we at Cities Service have been making a thorough study of the possibility of using atomic energy as a fuel abroad large tankers. In our studies, we have collaborated with many companies who are engaged in studying the atomic energy program and/or supplying hardware for the industry.

The operation of submarines with atomic power by the Navy has proved the feasibility of using the medium for propulsion of ships. In the case of the Navy, the ability to perform feats which would be impossible using conventional fuels amply justifies the extra cost incurred. We heartily agree that the Navy is to be highly congratulated on their success in these matters.

However, in the case of a surface ship carrying petroleum or dry cargo, no one has as yet envisioned using the medium to accompplish anything except to replace the present conventional methods of propulsion using fuel oil or diesel

oil for fuel. We do not see how the use of atomic energy would be a superior method of doing this; therefore, if it is to be attractive to a shipowner, it must be a cheaper way of doing it.

While the *Savannah* will amply demonstrate the feasibility of using atomic power as a propulsion medium for a ship, the next step in the program is to develop a vessel which will do this competitively. We believe that once a competitive or nearly competitive system has been devised, industry can and will carry the ball from there on.

However, the cost of performing research and development work in the atomic energy field is so large that in our opinion only the Government can provide the funds necessary to keep the state of the art in the United States ahead of, or at least on the same level, as our foreign competitors. In these countries, of course, the Government supplies the bulk of the necessary funds. It seems to us that if the proper funds and individuals are assigned to this ship project, it will be possible to realize our goals.

We are of the opinion that over the near term period the major effort as far as a ship reactor is concerned should be expended in trying to develop a competitive or nearly competitive system. This will eventually lead to the construction of a vessel by the Government to demonstrate the feasibility of the system developed.

In conclusion, therefore, we are of the opinion that only if our Government will bear the cost of the necessary research and development along the lines outlined above, will it be possible to develop a suitable reactor for competitive surface ship operation in this country.

Very truly yours,

E. G. MADDOCK.

EFFECT OF GOVERNMENT PRICING POLICIES ON THE DEVELOPMENT OF COMMERCIAL ATOMIC POWER

(By Gordon Kiddoo, Columbia-National Corp.)

A specific goal of the Government atomic energy program should be the development of power-producing reactors which will produce power from nuclear fuels competitively with other production methods and with reactors manufactured in other countries. The types of reactors which are ultimately developed will depend greatly on the form of the incentives established by the Government in its efforts to expedite the establishment of an atomic energy power industry. Government aid should be furnished in a way which will lead to the design of reactors suitable for use in a free and unmanaged economy.

A number of factors, now under direct Government control, directly or indirectly influence the designs of reactors now being developed. Among them are the prices and use charges (or waivers of use charges) for heavy water and natural and enriched uranium, the buy-back price for plutonium, and the reprocessing charges for spent fuel elements. If such prices or charges are established on any basis other than those which would prevail in a free economy, the reactors ultimately developed will not be of optimum design for a free and competitive market.

As producers of zirconium we have followed carefully the trends in reactor design in the United States and abroad and have studied carefully the influence of Government policies. Many of our studies in this field have been made by, or under the supervision of, Dr. Manson Benedict, professor of nuclear engineering at Massachusetts Institute of Technology.

We believe that the present use charge of 4 percent on the value of the uranium tied up in a reactor operation is too low; industrial concerns today cannot borrow money at this rate and utilities seek much higher rates of return on capital investment—on the order of 12 to 14 percent. We feel that today's low use charge encourages the development of reactors which carry excessive inventories or have too high an enrichment, or may result in a slow processing of fuel leaving the reactor. We, likewise, feel that a waiver of charges for fuel or heavy water may lead to waste of these materials.

It is true, of course, that a higher use charge more nearly typical of rates of return on utility investments will raise the cost of power generated from nuclear fuel. Our most recent study, in which fuel costs for pressurized water reactors were studied, shows that the cost of power is raised approximately 1 mill per kilowatt-hour with a use charge of 12 percent instead of 4 percent.

The range actually is from about 0.7 to 1.5 mills per kilowatt-hour, and varies with fuel burnup, enrichment, and cladding material. This differential in the use charge of 1 mill per kilowatt-hour approximates $800,000 per year for a typical 100,000-kilowatt nuclear powerplant.

This 4-percent use charge, rather than a charge at a higher rate, is a subsidy for the nuclear industry and should be so acknowledged. We recognize the present need for Government support of our nuclear power program and are in favor of it. At the same time, however, we feel that the present 4-percent use charge subsidy has a definite and unfavorable effect on the design of nuclear power reactors and may lead to reactor designs which will not be competitive in a free nuclear economy. This could be of considerable importance in our efforts to sell our reactors to other countries, which may not look to the United States for fuel, and might place our designs at a competitive disadvantage. For these reasons we believe that the use charge on fuel should be increased substantially to eliminate the technological bias inherent in the present use charge subsidy.

We believe that the most effective, and perhaps the only, way in which Government support can be given without distorting reactor designs is to contribute to each utility or reactor owner (not builder) a sum based on the capacity of the nuclear-fueled powerplant, or to its output over some arbitrary period, say 5 years. (In essence, these are essentially the same basis, inasmuch as utility powerplants tend to run at a fairly consistent load factor over an extended period.) This should represent an appreciable portion of the increase in capital costs over those for a conventional powerplant of the same capacity—perhaps Senator Anderson's suggestion of a grant covering up to 90 percent of this differential should be reconsidered.

With this contribution, the owner-operator of the power-generating utility has entire freedom to look over the designs of the several reactors offered for sale to him and to make his own selection as to the optimum design, balancing capital investment, and operating costs over the life of the plant. This means that to satisfy their utility customers, designers and builders of reactors will strive to design reactors which will produce power at minimum costs, considering both amortization of capital investment and out-of-pocket operating costs. The period of time and the quantity of support by the Government would be minimized by thus maximizing the incentives to private industry; when Government support is no longer necessary, it will be found that the atomic power industry will be established on a sound, competitive, economic basis which needs no continuing subsidies or price supports.

COMMONWEALTH ASSOCIATES, INC.,
Jackson, Mich., February 13, 1959.

Hon. CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D.C.

MY DEAR MR. ANDERSON: Your letter of January 27 inviting our testimony before the Joint Committee on Atomic Energy during its hearings on the development, growth, and state of the atomic energy industry is very much appreciated.

We have read the Joint Committee's staff report of last August, the AEC's ad hoc committee's report and the Edison Electric Institute's report, all of which deal largely with the political, economic, and technical objectives of the program. In this letter, we hope to bring to your attention some of the facets with which some people are familiar, we are sure, but which have often escaped public attention and recognition.

Commonwealth Associates, Inc., has been actively engaged in the nuclear power program since 1954, and at the present time is providing engineering services for the detailed design of the Enrico Fermi Atomic Powerplant at Lagoona Beach, Mich., and for certain facilities at the James Forrestal Research Center of Princeton University for thermonuclear research. As the progress in these particular areas will no doubt be reported by others, we felt that it might be of interest to the committee to receive some of our observations on nuclear power development activities which have been brought to our attention with much greater force than ever during the past year.

In nuclear power design engineering, we have observed that progress has been painfully slow in certain areas at times because few precedents were available for solution of the many difficult problems being encountered. Similarly, client

managements, manufacturers, constructors, and researchers are also encountering such problems in their special fields. Much attention has been focused on the difficulties of these problems with the result that the effort being directed toward their solutions is often overlooked.

In the engineering research and development fields, many problems are being encountered which, because of lack of technical precedents, require the very best judgment in their solutions. Many engineers in our own organization, as they are elsewhere all over the country, have been meeting such requirements by long hours of study in university extension courses and by other individual means. By our experience, we would estimate that three or more have had some excellent training for every engineer actively engaged on an actual project. In addition, every major engineering technical society has devoted significant portions of its technical programs to things atomic in recent years.

Manufacturers and constructors have also faced problems of retraining even skilled manpower in the production and construction of nuclear equipment and facilities. For example, a year or so ago we observed that welders, classed experts by ordinary standards, could make acceptable welds on certain stainless steel piping at the average rate of only about two-thirds of an inch an hour when they first undertook the work. Technical assistance, retraining, and experience over approximately a year's time has increased this rate well over three times, and welders' skills are still increasing. This is true also in other labor categories where it has been observed that workmen take tremendous pride and direct wholehearted effort toward performing individually an excellent job on the project. Recognition of these accomplishments appears to lead to excellent labor relations on most atomic projects.

We have observed that each power project, because of the nature, number, and variety of new problems, has required tremendous efforts for coordination of all activity so as to lead to the objective of creating a plant that will work. These efforts now are taking a lot of time and money, but are resulting in definite progress toward the realization of nuclear power in the United States.

We have recited some of these things because we feel that great reserves of management, technical, and labor skills for nuclear progress are being built up in this country at this time which mere statistics seldom disclose. In observing closely efforts of the various groups, we are sure, too, that the total of such effort by enterprises and individuals across the country would far exceed in value the dollars or other figures usually published to represent progress in the power reactor demonstration program.

Yours very truly,

By J. H. FOOTE, *Chief Engineer.*

STATEMENT BY WILLIS GALE, CHAIRMAN, COMMONWEALTH EDISON CO.

My statement for the 1959, 202 hearings of the committee covers (1) a general description of the Dresden project, (2) the current status of Dresden, and (3) my comments on the national program.

THE DRESDEN PROJECT

The Commonwealth Edison-Nuclear Power Group Dresden project was initiated through a proposal to the Atomic Energy Commission in March 1955. The capacity of the Dresden boiling water reactor plant will be 180,000 kilowatts. Its reactor is still the largest under construction in this country.

Commonwealth Edison Co. has a contract with General Electric Co. for the construction of Dresden, 50 miles southwest of Chicago, for $45 million. Bechtel Corp. is engineer-constructor for General Electric.

Commonwealth Edison will own and operate the plant and will pay and capitalize $30 million of the contract price plus something over $6 million in overhead and site costs.

The $15 remainder of the contract price is being paid as a research and development expense by the eight companies of Nuclear Power Group, Inc.; namely, American Electric Power Service Corp., Bechtel Corp., Central Illinois Light Co., Commonwealth Edison Co., Illinois Power Co., Kansas City Power & Light Co., Pacific Gas & Electric Co., and Union Electric Co.

Thus, the Dresden project is being financed entirely by private funds.

The General Electric contract price is payable in monthly installments over a 5-year period and $28,500,000 has been paid to date.

CURRENT STATUS OF DRESDEN

The design of the entire project is essentially complete. Final design features have been included in a recent amendment to the "Hazards Summary Report" filed with the Division of Licensing and Regulation of AEC. The Commission's Advisory Committee on Reactor Safeguards expects to review these amendments for licensing purposes at its March meeting. We believe that we are safe in assuming that the project will not be delayed because of licensing technicalities.

The major structures at the plant site have been completed except for the waste storage facilities which will not be needed until the plant is ready for operation. The containment sphere (190 feet in diameter) was completed and tested nearly a year ago. The secondary steam generators and most of the main pumps and heaters have been installed. Much of the piping and control facilities have also been installed. All other major equipment of a conventional nature has either been delivered or is on the way, including the condenser and the turbine generator. Nuclear fuel is being fabricated on schedule and one-third of the first loading has been delivered to the site.

The 300-ton pressure vessel for the reactor core has been loaded on a barge at Camden, N.J., and is in transit down the inland waterway to the Gulf of Mexico and up the Mississippi and Illinois Rivers to the Dresden site.

The contract requires completion of the project by December 7, 1960. The target schedule of General Electric Co. contemplates that the bulk of the long series of loading and startup tests will be completed before the end of 1959. It is expected that the plant will be in full operation by the middle of 1960.

COMMENTS ON THE NATIONAL PROGRAM

Turning to the national picture, I am very much encouraged to see that the long-range programs for reactor development proposed by the Joint Committee staff and by the AEC ad hoc committee show a fundamental agreement on the basic direction of future development. Both appear to agree that AEC should be assigned a stronger role of guidance particularly in the field of fundamental research and for broader research and development on new types of reactors and new fuels for reactors.

In basic principle, I see nothing in either the staff report or the ad hoc committee report to change the opinion expressed in my 1958 202 statement as follows:

"From the point of view of economics alone, atomic power in this country should be permitted to find its place in our economy in a process of normal and logical development. However, with the progress which is being and will be made in the rest of the world, where fossil fuel is scarce and expensive, it is doubtful if a normal orderly development here is practical. The American people are not likely to be satisfied to have other parts of the world ahead of us in this important field.

"Everything considered, it appears that our atomic power program in this country must be accelerated beyond the ability of private industry to carry the entire burden.

"There are many shades of opinion on this subject. I won't go into detail about these philosophies. But I would like to tell you how we at Commonwealth Edison feel about it.

"We advocate certain basic steps. These include:

1. That there be the maximum practical participation by existing utilities, coupled with a substantially expanded program of cost-sharing by the Federal Government.

2. That authority be given the AEC to make substantial outright cash contributions toward the capital cost of power reactors in addition to the existing research and fuel allowances.

3. That these atomic plants be built and owned by existing utilities, which would be required to put into their projects the full amount justified by competitive power costs.

4. That the Federal Government pay a substantial part, but not all, of the balance.

5. That projects be approved for both privately and publicly owned utilities.

6. That the amount of the Federal aid be split between the two roughly on the basis of the present amount of private power as compared with the present amount of public power in the country. This should entirely eliminate from our atomic program the question of public versus private power.

"It seems to us that the country will go faster and farther—and at less cost—along the road to competitive nuclear power by utilizing the know-how of existing utilities.

"If these utilities pay a substantial part of the cost, it will not only reduce the drain on the Federal Treasury; their participation will also give the utilities the experience of building and operating nuclear plants.

"The United States will not have a truly competitive nuclear power industry until the utilities, after careful study of relative costs, walk up to the counter and buy nuclear plants as a strictly business matter. Only actual experience in building and operating reactors can provide the basis for these decisions."

The joint committee staff report and the ad hoc committee report are at variance as to the need for the construction of large-scale plants. There appear to me to be valid arguments to support both sides of this question.

Whatever the final answer may be, it seems generally agreed that expanded governmental assistance will be necessary. In my opinion, the crux of the matter is, as I said last year, that the AEC should be given authority to make substantial outright contributions to the capital cost of power reactors in addition to the existing research and fuel allowances.

STATEMENT BY R. L. SCHACHT, GENERAL MANAGER OF CONSUMERS PUBLIC POWER DISTRICT

I am pleased to have the opportunity to, once again, review the participation of consumers public power district in the Commission's power reactor demonstration program. As you know, our activities are centered on the construction and operation of a sodium graphite reactor at the Hallman nuclear power facility. This program was outlined to you in our last communication to the Subcommittee on Legislation of the Joint Committee on Atomic Energy on February 27, 1958. Inasmuch as the background of our organization and our progress up to March of 1958 is a matter of record of this committee, I will confine my statement to the progress which has been made since that time.

Under the terms of our contract with the AEC, we are to provide an operable turbine generator facility by early 1961. This work is well underway, with 25 of the 36 major contracts required for construction having been let, and in some cases, the work underway. This represents a $13,700,000 commitment by consumers toward completion of our obligation under the contract.

At the present time, the site has been leveled, rail siding is being installed and wells are being drilled in order to provide a supply of water for the construction period as well as for operation. As quickly as the weather permits, probably in April, a full scale construction effort will be started at Hallam in order to provide complete weather coverage by completing the building shell in the fall of 1959. This will then permit a continuation of construction through the winters until full operation of the conventional facility is started in April of 1961.

The conventional facilities include a fossil-fueled boiler which will permit power production from the turbine generator equipment until the reactor installation is completed later in 1961 and full power operation is initiated early in 1962. After the reactor is operational, this boiler must then be released to provide steam for a second turbine generator which will be installed later.

The preliminary design of the reactor facility (title I) was completed in September and the final design was started in the latter part of October by Atomics International. Bechtel Corp. is carrying out the nuclear facility architect-engineer design responsibilities. The drawings and specifications for the reactor substructure, cavity liner and the building steel have been completed, and bids are being prepared by potential contractors. Certain other long lead time components are now on order. In addition, the results from research and development work being conducted by Atomics International, continue to build confidence that the proposed construction schedule can be met.

The operating experience now being gained by Atomics International on the Sodium Reactor Experiment located at Santa Susana, Calif. is supplying additional valuable backup information for many of the design and operating principles proposed for the Hallam nuclear power facility.

From the inception of this program consumers public power district has been convinced that this particular reactor concept offered unique advantages in the

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development of a major commercial source of gamma radiation. The principle operation consists of withdrawing a small amount of the primary sodium coolant into an adjoining radiation facility in a circulating system, in order to utilize the radioactive sodium. Inasmuch as this sodium appears as a complete byproduct of the major objective of producing electric energy, it had seemed to us that it would be possible to develop a minimum cost radiation facility as an expansion of the Commission's program at Hallam. A study of the entire project has just been completed by Atomics International, and a report entitled, "A Food Irradiation Facility," has just been submitted to the Commission for its review. As of the present, there has ot been sufficient time for consumers nor the Commission to analyze the feasibility of expanding the Hallam nuclear power program to include the irradiation facility. We are optomistic that the addition of this program could be a valuable contribution to one phase of the AEC isotope development program.

In summary, the entire program is being conducted in such a way that we should be able to meet the scheduled 1961 completion of construction of the conventional plant. Our activities to the present indicate that the contracting arrangement with the AEC provides a satisfactory vehicle for our participation in the power reactor development program. In our dealings with the Commission, it has been our experience that the staff of the Washington and Chicago Operations Office is willing to work out the individual problems as they arise although in many cases, requiring a considerable personal sacrifice of their time.

On February 11, 1959, Atomics International and Consumers' personnel were contacted by the Commission and requested to investigate the possibility of a construction delay for the Hallam nuclear power facility. Following this initial request, there were a series of meetings between the interested parties, and the analysis by Consumers' personnel resulted in a recommendation to the Commission on February 25 to continue on the present schedule. A copy of the letter to Mr. McCone which sets out these results is attached.

DAVISON CHEMICAL CO.,
Baltimore, Md., February 24, 1959.

Senator CLINTON P. ANDERSON,
U.S. Senate,
Washington, D.C.

DEAR SENATOR ANDERSON: Reference your letter to Mr. R. D. Goodall on January 27.

It is not our intention to testify or have representatives at any of the Joint Committee hearings on atomic energy. We would, however, like to make this statement setting forth our position as a member of private industry engaged in production of uranium and thorium reactor materials.

The production of uranium and thorium in the form of food materials for research or power reactor programs is now a well established industry and constitutes an integral portion of the overall fuel cycle. During the initial period of growth of the private power industry, the requirements for uranium and thorium in the form of their oxides and metals are not sufficiently large to permit application of the most economical production methods that would be used in a higher volume business. Consequently, the steps that the Atomic Energy Commission takes toward permitting the private feed materials industry to produce nonroutine Government requirements for these materials will have a significant effect on the cost of uranium and thorium from private sources to private users. The cost of power from private power reactors will thus be influenced proportionately.

Very truly yours,

T. C. RUNION,
General Manager, Reactor Materials.

STATEMENT SUBMITTED BY THE DETROIT EDISON CO.

The Detroit Edison Co. is a New York corporation engaged in supplying electric power to more than 1,240,000 customers residing in approximately 7,600 square miles in southeastern Michigan. Its sales to those customers in the calendar year 1958 totaled nearly 11.8 billion kilowatt-hours.

The company is pleased to submit this statement concerning the status of the nonnuclear facilities of the Enrico Fermi atomic powerplant, now under construction at Lagoona Beach, Monroe County, Mich., for inclusion in the record of the hearings being held during February 1959, by the Joint Committee on Atomic Energy, in accordance with section 202 of the Atomic Energy Act.

The nuclear facilities of this plant are being built, and will be owned and operated by Power Reactor Development Co. (PRDC), and a report regarding the status of that part of the project is being submitted in a separate statement by that company. In accordance with agreements between the Detroit Edison Co. and PRDC, Detroit Edison is building and will own and operate the conventional steam turbine-generator facilities adjacent to the reactor. Edison will purchase from PRDC the steam produced by the nuclear facilities. It will utilize this steam in its turbine-generator, and distribute the electricity produced in its existing power system.

In accordance with its longstanding practice, Detroit Edison is doing the engineering and detailed design of the nonnuclear facilities. This work is well over 80 percent complete and orders for nearly all components have been placed with appropriate suppliers.

Since August 1956, United Engineers & Constructors, Inc., has been engaged in general supervision of the construction work for Detroit Edison at the site. The entire construction schedule of the nonnuclear facilities is carefully coordinated with the PRDC schedule for the nuclear facilities.

THE STATUS OF THE SITE AND SITE DEVELOPMENT WORK

We reported at the hearings in March 1958 that site development work was largely completed. The condenser water overflow conduit was installed during the summer of 1958. The remaining site work largely involves (1) the dredging of the condenser water intake canal, and (2) cleanup operations after the major construction work is completed.

BUILDINGS AND EQUIPMENT

The substructure for the steam turbine-generator building was completed in December 1958. Erection of structural steel began early in February this year and will be completed some time in March or April. Completion of the building and the installation of all equipment will follow in an orderly manner.

The steam turbine-generator, with a capacity of 156,000 kilowatts (electricity) is being manufactured by the Allis-Chalmers Manufacturing Co. and is scheduled for delivery to the plant site in April 1960. Although the initial rated capacity of the plant is 100,000 kilowatts, the larger turbine-generator is being installed to accommodate a possible increase in overall capacity as operating experience is gained.

We believe that the turbine-generator and related auxiliaries will be installed and ready to receive steam in August 1960, which corresponds with the schedule for initial nuclear operation of the reactor.

COST OF NONNUCLEAR FACILITIES

In the original proposal to the Atomic Energy Commission concerning this project, submitted in 1955, the estimated cost of the nonnuclear facilities was given as about $14 million. During the intervening period, there has been a substantial increase in prices and labor rates. In addition, it has been necessary to make special arrangements of piping and equipment to provide conditions which are compatible with the requirements of the nuclear reactor.

Our present estimate of the cost of the nonnuclear facilities is approximately $17 million, as follows:

Feb. 12, 1959

Item:	
1. Site and improvements	$1,210,000
2. Turbine plant structure	1,800,000
3. Turbine plant equipment	10,950,000
4. Accessory electrical equipment	1,100,000
5. Substation and transmission	1,170,000
6. Engineering and design	570,000
7. Interest during construction	200,000
Total	17,000,000

Indirect costs and contingencies are included in items 1 through 5.

Because of the advanced state of the project, it is believed that the present estimate is reasonably firm. Detroit Edison's method of applying interest during construction has been revised upward since 1955 to correspond with the more commonly accepted practices. The amount shown herein is in accordance with the 1955 practice for comparative purposes.

ATOMIC INFORMATION CENTER

Since 1951, when the company first became actively engaged in atomic power development, there has been a widespread and ever-increasing public interest in atomic energy. We have endeavored to satisfy that interest by meeting with numerous groups and explaining the significance of atomic energy in the modern way of life.

Ever since field construction of the Enrico Fermi plant began, continued requests have been made by individuals and groups to visit the plant site. In order to meet this situation, Detroit Edison in 1958 built an atomic information center on the edge of the plant site where guests are received and atomic matters are discussed and illustrated. The center contains a comprehensive atomic energy exhibit and a small area where movies can be shown and lectures delivered to approximately 60 visitors at one time. It is open to the public from 10 a.m. to 4 p.m., Tuesdays through Saturday.

Between August 1, 1958, when the center was opened to the public, and February 1, 1959, approximately 20,000 visitors had been received. The more than 190 groups that visited the center during that period range from those attending the American Nuclear Society meeting in Detroit last December to grade school science classes. It is anticipated that the number of visitors will exceed 50,000 per year.

Detroit Edison plans to continue the center as long as the public interest requires.

In addition to the atomic information center, representatives of the company gave nearly 200 talks on atomic energy before clubs, service groups, schools, and church groups during 1958. The audience totaled more than 14,000 people.

Respectfully submitted.

CHAS. R. LANDRIGAN,
Executive Vice President.

(See also Power Reactor Development Co. statement, p. 461.)

F. H. MCGRAW & Co.,
New York, N.Y., February 20, 1959.

Mr. JAMES P. RAMEY,
Executive Director, Congress of the United States,
Committee on Atomic Energy, Washington, D.C.

DEAR MR. RAMEY: As suggested, we are submitting the following statement for the record in the hearings scheduled for February 18–26.

In view of the relatively large supplies of comparatively low-cost fossil fuel available in the United States, as compared, for example, with Great Britain and many of the Euratom countries—even though this country is the most advanced technologically in the world—it also needs nuclear power less than most other industrial nations. This is another way of saying that the most difficult area for nuclear energy to compete commercially with energy generated from fossil fuels is probably in the United States. Because of transportation costs and similar factors, this is true in some areas in our country more than in others but nonetheless it is substantially true for the entire country. This observation applies primarily to single purpose power producing reactors. It is our feeling, therefore, that the development of dual purpose reactors is likely to make nuclear power sooner competitive in this country than the development of reactors for power generating purposes alone. Dual purpose reactors, of course, would include any reactor developed to have useful application for more than one purpose. For example, a reactor designed to produce thermal energy for use in generating electric power but also functioning as a "breeder reactor" and thereby producing, for example, plutonium as a byproduct must be classified as a type of dual purpose reactor. Similarly, a reactor which basically produced either steam or high temperature high pressure water for generation of steam but also produced additional thermal energy for space heating or promoting chemical reactions, evaporating materials, tec., would be another type of dual

purpose reactor. While not excluding reactors of these types, we believe that attention should be given to the development of a different type of dual purpose reactor, specifically one in which the radiation generated within the reactor is first used as radiation proper and secondly for generation of thermal energy and thereby electric power. Of course, a breeder reactor falls into this category, but we feel that the use of radiation to promote chemical reactions or to effect physical transformations in materials may provide a quicker method of getting nuclear energy on a commercial basis in this country than some of the other approaches already under investigation.

At the present time in all reactors of which we have knowledge, with the exception of the "breeder" type, the very high level energy represented by the immediate effects of the general reaction is degraded to a relatively low order of thermal energy so that steam may be produced and electric power generated or hot gasses produced which could drive a gas turbine. Not only is the high order energy degraded or "throttled" but unfortunately in reactors such as the Shippingport reactor or even those used for naval purposes, limitations on structural materials, etc., mean that the steam which is generated is not of as high a temperature and pressure as in good fossil fuel powerplant practice today. This means that not only is the energy less efficiently used in the reactor complex itself but it means also that the conventional steamplant associated with the reactor boiler complex is larger, less efficient, and relatively more expensive than the turbogenerator units that would be required in a conventional steamplant of the same capacity fired by fossil fuel. In other words, the achievement of competitive nuclear power suffers in present approaches a double handicap which must be overcome. An analogy would be if steam were generated in a conventional plant at the highest obtainable temperatures and pressures and then for no useful reason throttled to a lower temperature and pressure, the energy in the throttling process being substantially degraded before converting it into electric power through a turbogenerator unit. Obviously, commercial plants are not designed along these lines. Of course, if for the uselessly degrading "throttling valve" in the above example we were to substitute a desirable and economically advantageous industrial process, we would change the economics of the installation very drastically in the direction of practical and commercial usage.

Many of the chemical reactions that are important today—for example, the catalytic cracking and reforming of petroleum, fixation of nitrogen, etc.—are carried out under conditions of high temperature and pressure, oftentimes in addition using catalysts to effect the reaction. The reason for this is that in order to get a sufficient number of molecules to react, it is necessary to raise the available energy level of the molecules high enough so that a statistically significant portion of them will get above the so-called threshold energy necessary to achieve reaction. If energy can be introduced into a similar number of molecules or larger number by, for example, direct radiation, it is conceivable that the same effect can be obtained without the high temperatures, pressures, or catalytic intermediaries. We are familiar with some limited amount of work already done in this direction. Undoubtedly a great deal more is underway indicating that the radiation properly applied can be used for such purposes. For example, experiments have been made on the formation of nitric oxide from nitrogen and oxygen under radiation at standard temperatures and pressures. Similarly, the work which has been done in changing the properties of polyethylene by irradiation is well known. Some progress has also been made in using radiation as a means of sterilization and, of course, investigations have been made in this area for food preservation. We believe that this work should be encouraged and supported by industry and, to the extent that Congress thinks it appropriate, by the Government because to the extent that it is successful, it would in effect mean that radiation could be used first for something for which it was basically and fundamentally efficient and only secondarily used in its degraded form for the production of thermal energy leading to the generation of electric power. We feel that even if the direct conversion of radiation to electric energy progresses, the above principles will still apply and that, therefore, this approach should not be disregarded on the basis that it might be obsolete before it could pay off.

The committee is undoubtedly aware that one of the problems in determining the economics of nuclear energy for commercial power generation is the problem of recycling spent fuel. This problem in turn is complicated by the fact that hot materials must be handled in process. The idea of dual

usage of radiation outlined above might very conceivably be the key to commercial application in this area, too. It is conceivable that these two effects could be so interlocked that the design of the reactor itself would be influenced first by the manner in which the radiation would be used primarily as radiation and secondly, how the secondary radiation available in the reprocessing of the reactor fuel could also be used. We are not familiar with any Government-sponsored work in this field although, of course, there may be work going on with which we are not familiar for reasons of secrecy. We feel that the prospects are too good, based on the limited work which is available, to be disregarded and possibly are worthy of support in the experimental and development area. In a sense, those experimental reactors already built which are used to radiate materials in order to determine how they behave under intense radiation could be regarded as dual purpose reactors in the above context. Perhaps, therefore, the program could be initiated merely by redirecting the effort and the usage of available radiation in some existing installations. We feel this should be investigated and if this is not practical, consideration should be given first to some studies of appropriate perimeters. If these studies indicate, as we feel they will, economic advantages, then as the next step it should be possible to schedule some appropriate experimental work which could be done without construction of a special dual purpose reactor; if this second step would progress favorably, then a third step of designing and building a prototype reactor of this sort should be undertaken.

In general, we feel that it is highly probable that commercial nuclear power will be first achieved in this country by what is basically a chemical or other material processing complex where radiation is used first to accomplish what only it can accomplish most economically, and secondly, to generate electric power more as a byproduct of the industrial complex rather than a primary objective. F. H. McGraw & Co. feel that it has facilities and qualifications to undertake some of the preliminary work in this field and it is preparing itself to become a qualified contractor in this area.

Very truly yours,

MILTON F. MEISSNER,
Member of the Board of Directors.

THE FLUOR CORP., LTD.,
Los Angeles, Calif., February 9, 1959.

Re public hearings on the development, growth, and state of the atomic energy industry.

Mr. GEORGE F. MURPHY, Jr.,
U.S. Capitol Building, Washington, D.C.

DEAR MR. MURPHY: In response to the Honorable Clinton P. Anderson's letter on the above subject, about which we wrote you on February 6, we appreciate the opportunity to make the following comments:

1. Government power reactor policies and programs

It is our belief that a number of prototype powerplants, using promising reactor types, should be built rather than a few large plants based on the most advanced technology. Since these prototype plants are not expected to be competitive with conventional fuel plants, it is recommended that private industry be encouraged to participate by supplying hardware and services equivalent to competitive conventional fuel plants for the location selected. The Government should make up the difference, including research and development and other unusual costs. This program appears preferable to one in which the Government assumes the entire cost of the prototype plants. If private industry has a participating interest in the nuclear powerplant program, it is believed the overall progress will be greater than will be possible under a program sponsored solely by Government funds.

2. AEC program for nonelectric power applications

We believe that a process heat program should be undertaken immediately with Government support. Process heat from reactors has a promising future, particularly in applications where long-range payout for the plant is possible. An example is the conversion of sea water to fresh water using reactor heat for distillation of the sea water. Process heat for chemical plants is less promising due to the practice of using shorter payout periods. Even here

the long-range prospects are good because of the less severe technical requirements of the low temperature reactor, compared with the high temperature reactor required for powerplants.

3. Government program for nuclear maritime propulsion

No comment.

4. AEC policy on declassification and dissemination of information

From our point of view, the AEC policy is satisfactory and a good job is being done in making information available to industry.

5. AEC's supporting services to the reactor industry

No comment.

6. AEC contract policy in the reactor development field

The policy, as such, is satisfactory but administrative procedures seem unwieldy and take longer than appear necessary. It is recognized that certain safeguards are necessary. If these could be streamlined, the contractors' work would be facilitated and could be made more efficient.

7. Organizational and administrative problems

We believe further improvements could be made to reduce organizational and administrative bottlenecks. This is somewhat categorical as it applies to Government procedures in general. In our experience, the AEC is more efficient than most other governmental agencies in administering a program after the policy is determined. Our criticism in this area would be directed mainly at what appears to be a procedure of determining the budget essentially by technical requirements, with the ultimate expenditures influenced largely by political considerations. This tends to create discontinuity and a reduced rate of progress in carrying out the technical program.

8. AEC isotope development program

No comment.

Very truly yours,

J. S. FLUOR, *President.*

GENERAL PUBLIC UTILITIES CORP.,
New York, N.Y., February 18, 1959.

Hon. CLINTON P. ANDERSON,
Joint Committee on Atomic Energy,
Washington, D.C.

DEAR SENATOR ANDERSON: Referring to Mr. Tegen's letter to Mr. Murphy of February 6, 1959, and in further response to your letter to Mr. Tegen of January 27, 1959, I am enclosing for inclusion in the records of the 1959 202 hearings, along with this letter, a statement describing the status of our Saxton "hook-on" reactor project.

Your letter of January 27 also asks for comments on the Commission's recent ad hoc committee report and further observations on the Joint Committee's staff report of last summer.

With respect to the latter, our letter to Mr. Ramey of October 28, 1958, covered our comments.

As to the ad hoc committee report, we have naturally taken special note of those features of the report which seem relevant to our Saxton "hook-on" reactor. We observe that the report stresses the importance of work on fuel cycle and fuel fabrication, the interest which the report displays in making further efforts to improve water-type reactors, and the need for doing work on nuclear superheat. We hope that our project will contribute to these objectives. At all events the policy that has guided us in proceeding with our projects has been directed to making a contribution along these lines.

Sincerely yours,

E. W. MOREHOUSE, *Vice President.*

STATEMENT BY GENERAL PUBLIC UTILITIES CORPORATION FOR INCLUSION IN THE RECORD OF 1959 SECTION 202 HEARINGS

The purpose of this statement is to recapitulate and bring up to date information previously supplied to the Joint Committee in our letters of February 25, 1958, and January 14, 1959, regarding plans for the Saxton hook-on reactor project.

As reported to the Joint Committee in our recent letter of January 14, 1959, a firm basis of agreement has now been reached with the Westinghouse Electric Corp., which we expect to result in a contract for the installation of a small developmental reactor at the Saxton, Pa., generating station of one of our subsidiaries. This reactor is to be connected with existing generating equipment and will be used for the conduct of a research and development program with primary emphasis on achieving cost reductions and increased efficiency in the use of nuclear fuel. The information developed from that program should be valuable to us and the utility industry as well. The program includes provision of a loop for use in conducting experimental tests in the reactor in order to obtain the detailed information needed for the design of a nuclear superheater, a factor to which we attach particular significance since nuclear superheat may well be a decisive element in the ultimate development of economically competitive electric power from water reactors.

The developmental reactor will have a nominal power rating of 5,000 kilowatts (electrical). It will consist of a single pressure vessel, heat exchanger, pump, pressurizer, and necessary auxiliaries erected in a containment vessel. Steam from the heat exchanger will be supplied to an existing 10,000-kilowatt (electrical) turbine in the Saxton station which will allow operation at power levels in excess of nominal. Initially, the reactor will use uranium oxide stainless-steel-clad fuel elements.

The hook-on concept has the immediate advantage of reducing total investment by eliminating the need of purchasing new electrical generating equipment. It also has the advantage that continuity of station operation can be maintained through the use of existing conventional steam generating facilities whenever it becomes necessary or desirable to shut down the nuclear reactor. We will not have to place the same emphasis on continuity of operations of the reactor that would be necessary in a large-scale nuclear plant. By limiting the size and scale of investment so that the hook-on reactor can be considered as an experimental and expendable plant devoted to the development of the art, we can afford to push it to the limits of performance consistent with safe operations, and in this way should be able in a relatively short time to obtain data which will be useful in the design of new reactors as well as in the operation of large plants already under construction.

The project will be a cooperative effort involving the GPU system, Westinghouse, and Gilbert Associates, Inc. Westinghouse will supply the reactor and associated equipment to the GPU system for a fixed price of $6,250,000. The GPU system will supply the plant site, make the existing turbine available, and bear the net operating and maintenance and insurance costs, estimated at approximately $2 million. Westinghouse will be responsible for the nuclear fuel requirements of the project for an operating period of 5 years, including fabrication and processing costs. Westinghouse will also make substantial contributions of manpower and facilities in connection with the overall research and development efforts. Gilbert Associates, Inc., has been retained by Westinghouse as architect-engineer and supervisor of construction.

The estimated construction schedule allows a 30-month period between execution of the definitive contract and the achievement of criticality. Negotiations on the definitive contract are actively underway and are proceeding satisfactorily. Steps are also being taken to form a new corporation which will own and operate the reactor plant and which will execute the definitive contract with Westinghouse. All of the domestic operating companies in the GPU system will participate in the new corporation and will supply through it the necessary funds for the project. We are hopeful that all of the necessary steps leading to execution of the definitive contract will be accomplished by the end of March or early April.

The proposed site for this reactor is in a relatively sparsely populated area in a mountainous region in south-central Pennsylvania. The only community in the proximity is the town of Saxton, Pa., with a present population of approximately 1,000. As such, this location appears to us to be a favorable one for a small nuclear plant but naturally appropriate applications will be made as soon

as possible requesting the necessary construction permits. Work has already started on the assembly of detailed site information, including meteorological data, and on preparation of the preliminary hazards report.

We believe that this project will do its small part in continuing forward with the time-consuming and often thankless problems of fuel development and improvements in detailed operating conditions. All this is in keeping with our view that one effective way to make progress toward economic nuclear power is through the pattern of step-by-step improvement—the same pattern which has brought power generation by conventional fuels to its present levels.

THE H. K. FERGUSON CO., INC.,
Cleveland, Ohio, March 13, 1959.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy, Congress of the United States, Washington, D.C.

DEAR MR. RAMEY: Enclosed please find two copies of our writeup on the sea transportable nuclear power station.

We believe this to be a rather interesting method of rapidly building small size nuclear power stations in the United States for use in remote areas throughout the world, where power costs of 15 to 20 mills are quite competitive today. As the report points out, the plant has two major advantages. First, it can be built rapidly and at low cost in a large manufacturing establishment in the United States. Secondly, it can be transported to any harbor in the world and put into operation within a few weeks of its arrival.

We would appreciate your considering this material for insertion in the record of the 202 hearings which the committee has recently completed.

Sincerely,

EDWARD L. HELLER,
Director, Nuclear Division.

TWENTY-THOUSAND-KILOWATT (ELECTRICAL) SEA TRANSPORTABLE NUCLEAR POWER STATION

INTRODUCTION

This booklet describes a nuclear powerplant concept for supplying power in remote areas having access to navigable water. Thule, Guam, Alaska, Antarctica, the seaport and river towns of Central and South America, Africa, and Asia are the potential users envisioned in this concept. From an economic standpoint, the plant will produce 10,000 to 40,000 kilowatts of electric power at at cost of 15 to 20 mills. Capital costs are estimated to run from $5 to $12 million.

The concept offers new techniques for constructing a nuclear powerplant. The powerplant can be built and tested in a large industrial complex located within the United States. Thus, the plant can be built in a minimum of time by highly skilled labor equipped with a wealth of production machinery.

After testing at its construction base, the plant can be towed to its remote location and installed quickly by a small crew of experts assisted by local common labor using only the equipment aboard. Thus, the expensive and time-consuming work of setting up construction operations in a remote area is eliminated. These savings will exceed the cost of the floating equipment by a substantial amount and will result in completion many months earlier than field construction would permit.

The Armed Forces are an immediate customer for this concept of a nuclear powerplant and it can be a powerful adjunct to the Atoms for Peace program in the undeveloped countries. The plant costs are competitive in these areas. It covers the size range which fits their needs. Fabrication and construction are carried out in the United States where cost and completion time are under close control. The plant can be fully tested before shipment and installation is simple and rapid.

Finally, once the prototype is developed repeat orders will resut in rapidly declining costs, for they can be filled in the United States in facilities where all the techniques of mass production can be effectively employed.

A market for several units per year is waiting.

GENERAL DESCRIPTION

The sea transportable nuclear powerplants described herein are designed for a net electrical output of 10,000 to 40,000 kilowatts. A typical 22,500 kilowatt (electrical) plant is shown in the accompanying drawings. A few of the uses for this type of nuclear powerplant are:

(1) Power generation for isolated locations.

(2) Temporary or supplementary power while larger powerplants are being constructed.

(3) Emergency power during disasters or military emergencies (powerplant knocked out by attack, typhoon, earthquake, etc.).

The design concept for these plants is a result of a pooling of the engineering and construction techniques and experience of the H. K. Ferguson Co., the parent company, Morrison-Knudsen Co., Inc., and the nuclear manufacturers whose designs are represented herein.

The H. K. Ferguson Co. has been active in many phases of the nuclear field since the early days of the Manhattan District project, and is currently engaged in extensive nuclear design and construction projects for the U.S. Government and private industry. The interest of Morrison-Knudsen in this nuclear application stems from their 40 years of construction activity in conventional power stations, their extensive experience working in remote locations and their experience with similar prefabricated sea transportable structures such as Texas Towers.

These plants feature prefabricated assembly of the complete units at a waterside industrial facility, transportability to any site accessible by waterways with a minimum 15-foot channel, and quick, easy installation at the site.

These plants are complete power generating stations with auxiliaries, mounted in oceangoing barges, with integral hydraulic jacking caissons for supporting the entire barge-reactor unit at the selected site.

These power stations are available using any of the three tried and proven nuclear systems as designed by outstanding nuclear manufacturers. Studies have been made employing the following reactor types: (1) the organic moderated reactor system (OMR) designed by Atomics International, a division of North American Aviation, Inc., (2) the pressurized water reactor system (PWR) designed by Babcock & Wilcox Co.'s Atomic Energy Division, and (3) the boiling water reactor system (BWR) designed by Nuclear Products-Erco Division of ACF Industries.

	OMR	OMR	PWR	BWR
Power output:				
Net electrical kilowatts	11,400	20,000	20,000	20,000
Gross electrical kilowatts	12,500	22,200	22,000	22,500
Gross thermal kilowatts	45,500	80,000	75,000	72,600
Steam conditions:				
Steam pressure, p.s.i.a.	415	415	515	615
Steam temperature, °F	550	550	448	488
Steam condition, degree	100	100	(1)	(1)
Steam rate, pound per hour	[2] 162,000	[2] 288,000	280,000	280,000

[1] Saturated. [2] S.H.

BARGE AND INSTALLATION

The nuclear generating plants are housed in an oceangoing barge. These barges are 150 feet long by 70-foot beam by 20-foot draft, with full ballast (15-foot draft without ballast), and with a 13-foot freeboard.

The barge is of all steel, double hull construction and is integrally equipped with hydraulically jacked caissons. The caissons are mounted along each side and arranged so that the load of the vessel and its contents are equally distributed between them. The sides are heavily reinforced to act as plate girders so that the entire assembly can be elevated out of the water by the caissons. The space between caissons is used for ballast tanks.

The barge is divided into shielded and unshielded compartments. The mechanical equipment and reactor are located in these compartments. All equipment which is a potential source of radiation is located in a shielded compartment, while the remaining equipment is located in the unshielded portion.

The barge will be fabricated complete with bulkheads and shielding in a conventional manner. After launching it will be fitted out with the mechanical equipment in a regular fitting basin. When the fitting-out is complete, the entire system can be checked out and tested under operating conditions (without nuclear fuel) using dummy fuel elements during flow tests.

After the tests are completed, the power station is ready to be towed to any selected site for installation, using conventional towing equipment.

Following successful operation of the first generation of these plants, power could be produced within a month of arrival at the site.

Delivery of the equipment can be obtained in a maximum of 12 months after placement of firm orders, so that construction and testing in an 18-month period is possible, once the original engineering design is completed.

For permanent or semipermanent installation, it is anticipated that a short channel would be dredged at the site to receive the barge. The plant would then be towed into this channel and jacked into position with the caissons. If it is desired, the channel may be filled in around the plant to provide additional shielding and easy access, or the barge may be left with the bottom and sides exposed.

For temporary or emergency installation, the barge would be located close to shore or along a dock and jacked up only enough to be unaffected by tide and wave action. Temporary electrical lines would then be installed from the plant to connect to the local transmission or distribution system.

Units held in reserve could be quickly moved to disaster areas or used to meet local needs while new power stations were being built. Following completion of the new plant or repairs after the disaster, the sea transportable powerplant could be moved to another area or put in reserve.

CITY OF HOLYOKE, MASS.,
GAS & ELECTRIC DEPARTMENT,
February 21, 1959.

JOINT COMMITTEE ON ATOMIC ENERGY,
U.S. Capitol, Washington, D.C.

The city of Holyoke (Gas and Electric Department) wishes to avail itself of this opportunity to reaffirm its interest in the development of nuclear electric power and particularly in the development of the gas-cooled reactor concept as applied for this purpose.

About 2 years ago the proposal of this department for the design, construction, and operation of a 15 E.M.W. gas-cooled reactor plant was rejected by AEC on the ground that the concept was "technically premature." An official of the AEC staff stated that the rejection of the Holyoke proposal was "a matter of judgment."

Within the past 2 years, however, there has been a vast increase in interest in the gas-cooled concept. This interest has been evidenced by industry, utilities, the Joint Committee, and the Atomic Energy Commission. The British are further developing this concept, the feasibility of which has already been demonstrated at Calder Hall.

The officials of this department are still convinced that the goal of economic nuclear power can best be achieved by the development of high temperature reactor types. High temperature operation will permit utilization of power generating equipment of high thermal efficiency in accordance with accepted modern utility practice. This is of particular advantage to the small utility.

The one high-temperature reactor type that seems capable of realization today is the gas-cooled concept. For this reason the officials of this department are convinced that the rapid development of the gas-cooled concept is imperative in the public interest.

We are pleased to have been among the first in this country to recognize the inherent possibilities and advantages of the gas-cooled reactor concept as evidenced by our proposal of February 1, 1956.

We hope that in the near future we will again be in a position to participate in a program leading to the construction and operation of a gas-cooled nuclear plant. Holyoke has maintained its interest in and has continued its study of the application of this design to our steam- and power-production require-

ments. We are more than ever convinced that the successful development, construction, and operation of a plant of this type will be of immense benefit to the utility industry and to the Nation as a whole.

We wish to thank you for the opportunity to present this statement of our views.

Respectfully submitted.

FRANCIS H. KING,
Manager.
DONALD M. BALLOU,
Nuclear Project Officer.
JOHN F. MORIARTY,
Department Counsel.

INTERNUCLEAR CO.,
Clayton, Mo., February 18, 1959.

Hon. CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy, Congress of the United States, Washington, D.C.

DEAR SENATOR ANDERSON: Thank you for your letter of January 27, 1959, and I am pleased to submit this statement for your hearings pursuant to section 202 of the Atomic Energy Act of 1954.

The subject on which I am perhaps best qualified to comment is the first on your list, "The Government's power reactor policies and programs, both domestic and foreign."

It has seemed to me for several years that the prime objective of our civilian nuclear-power program should be to fortify our position of leadership abroad, and I am glad to see this objective acquiring increasing prominence in your staff report of August 1958, in the Commission's ad hoc committee report, and, of course, in the cooperative program with Euratom.

There are two reasons for giving emphasis to this objective: First, the greater urgency which attaches to nuclear-power development in certain other countries can lead to near-term construction and operation of reactors in those countries, thus providing an opportunity for proving ground experience which can help us to attain the goal of competitive nuclear power in this country; second, such leadership can make a large contribution to carrying out the "atoms for peace" objectives.

I am also pleased to note the emphasis which is being given to research and development in relation to the construction of full-scale plants. In fact, it may turn out that the joint research and development program becomes the most important aspect of the agreement between the United States and Euratom. Also, the emphasis which the ad hoc committee places on the construction of prototypes is, I believe, sound. This will help utility companies, both here and abroad, to acquire the data to judge whether or not the time has come for them to begin investing in nuclear equipment.

In summary, I believe that the elements of a sound program are beginning to emerge from the thinking which led both to the August staff report and the Commission's ad hoc committee report.

If I can be of any possible service, please call on me.

Sincerely,

PHILIP N. POWERS, *President.*

KAISER ENGINEERS,
Oakland, Calif., February 16, 1959.

Hon. CLINTON ANDERSON,
Chairman, Joint Committee on Atomic Energy,
Congress of the United States, Washington, D.C.

DEAR SENATOR: In response to your invitation, we are pleased to take this opportunity to express certain views on matters pertaining to the development, growth, and state of the atomic energy industry.

A. THE GOVERNMENT'S POWER REACTOR POLICIES AND PROGRAMS, DOMESTIC AND FOREIGN

We believe that, considering the diversity of the U.S. approach toward the development and optimization of nuclear power, the technical progress to date has been good.

We have studied the report of the Atomic Energy Commission's Ad Hoc Advisory Committee on Nuclear Policies and Programs, and find that our views

coincide very closely with the statement of objectives and the recommendations of that group. We believe the ad hoc report is consistent with the Joint Committee's objectives of expanding and expediting the development of nuclear power reactor technology. We are particularly in agreement with the ad hoc committee recommendations that the Atomic Energy Commission program include prototype plants to develop and improve various nuclear power reactor types and components in lieu of full scale plants, where the prototypes are large enough to demonstrate adequately the operating characteristics of a full scale operation. We believe, as does the ad hoc committee, that this represents the quickest and most economical approach to an early realization of economic nuclear power based on the optimization of reactor concepts and components.

It is our view that Government support—including, where appropriate, assistance in capitalizing the facilities—is proper to insure not only that all of the likely reactor types are investigated; but also to insure that the second, third and subsequent generations of those reactor types that prove to have the potential for further optimization be built as rapidly as the technology can mature to support them.

The program of conducting design studies at AEC expense, such as was involved in the gas-cooled power reactor design studies performed by our company and ACF industries, is an appropriate means of fostering the development of promising reactor concepts.

With reference to the Euratom program, at the present time the only way that U.S. companies will enjoy any long-range benefit from the introduction of U.S. reactor technology into Europe, will be as the result of their establishing licensing and other working arrangements with European companies. We feel that any reasonable steps that can be taken to assist U.S. firms in the worldwide nuclear power market, would be very desirable. One such step is that appropriate arrangements should be made in order that U.S. individuals and firms at large can obtain patent protection in foreign countries for developments and discoveries, even though such items have been developed under Government auspices.

B. THE ATOMIC ENERGY COMMISSION'S PROGRAM FOR NONELECTRIC POWER APPLICATIONS

We believe that the development of nuclear reactors for process steam or process heat should be encouraged, and we suggest that one way in which this might be accomplished with a number of benefits to the country, would be to support a joint effort between the Atomic Energy Commission and the Office of Saline Water for the design and construction of one or more saline water conversion plants utilizing nuclear energy as a source of heat. The selection of the reactor type and plant design should be optimized by appropriate Government-financed engineering studies.

C. THE GOVERNMENT'S PROGRAM FOR NUCLEAR MARITIME PROPULSION

It is our belief that the advantages of nuclear propulsion for ships is sufficient to justify fully the present development programs; and, in fact, to warrant somewhat greater emphasis than at present on the optimization of economic propulsion plants for merchant application.

The development of economic systems for this application is of importance both for the United States and abroad.

D. ATOMIC ENERGY COMMISSION'S CONTRACT POLICY IN THE REACTOR DEVELOPMENT FIELD

We think it proper that the Atomic Energy Commission should continue to find means of obtaining from private sources as many of the services related to the AEC program as is possible. We think it is very significant that the AEC has found it possible to contract for feed materials processing on such a basis, and that the Commission is now undertaking to obtain a substantial amount of nuclear irradiation services from private companies.

In connection with the contracts that the Commission will enter into for services, the relatively short economic life (as contrasted with physical life) of test reactors, chemical processing plants, and the like, must be taken into consideration.

E. COMMENT ON THE AEC BUDGET

We have noted the views of the U.S. Chamber of Commerce on the AEC budget, and concur in their recommendation that it would be very helpful if it could be prepared in such a fashion that the nonmilitary items could be clearly examined, separately from the military items.

We hope that these views will be of assistance to the Committee, and we appreciate the opportunity given to us to express them.

Very truly yours,

KAISER ENGINEERS,
DIVISION OF HENRY J. KAISER CO.,
DAVID F. SHAW, *Vice President.*

STATEMENT BY MALLINCKRODT CHEMICAL WORKS, ST. LOUIS, MO.

Some 17 years ago, the privately owned facilities of Mallinckrodt Chemical Works, St. Louis, Mo., were utilized to purify the uranium oxide which—in the form of oxide and as metal processed from the oxide by others—was used in the first Chicago pile which went critical in December 1942. Since this work, done under an informal contract with the OSRD even before the Manhattan Project was organized, Mallinckrodt has been a continuous contractor of the Government in supplying uranium metal and compounds for our national nuclear program.

We have done this work under a variety of conditions. Some of it has been done in facilities which we owned and which were located on our land; some has been done in Government-owned facilities located on our property; and, in more recent years, we have operated Government-owned facilities located on Government-owned land. We have operated under several different contractual arrangements including unit price, modified unit price and cost plus fixed fee. We have seen production rates increase from a few hundred pounds per day to many tons per day, and we have seen (and contributed to) many technical advances. As a result of technical improvements and increased production rates, we have been able to provide the Government with better and better products at ever decreasing costs over a period of almost 17 years.

We believe there is a real parallel between our past experience in manufacturing normal uranium metal and compounds and the current and near future situation in the nuclear fuels industry. As far as the cost of nuclear fuels and fuel elements are concerned, we believe our experience definitely indicates that with a reasonable volume of production, and the technical advances which will accompany such increases, that portion of the cost of nuclear power attributable to fuel costs will be reduced at a rate much greater than is generally predicted.

We cite as a case in point, our own recent experience in the commercial nuclear fuel business. In 1956, Mallinckrodt built the first privately owned plant in the world to process enriched uranium hexafluoride to uranium dioxide, uranium metal and other compounds suitable for use as fuels in privately owned reactors. This business is still small; but even so, in less than 3 years, improved techniques and increased volume have enabled us to reduce our prices generally to considerably less than one-half of those in effect during the first year of operation. Because the volume of business is still relatively small and because we are spending a large percentage of our income on research and development aimed at future cost reduction, our commercial nuclear fuel business has not yet become a profitable one. That we have faith in the future, however, is evidenced by the fact that we, a relatively small company, have now invested some $2 million in our private nuclear fuel business.

Our faith in the future, represents in a sense, faith in the Government to foster a healthy nuclear industry and to achieve economically nuclear power in a reasonably short period of time. The power industry says it is willing to build more reactors if costs, including fuel costs, are reduced to a reasonable level. We in the fuel and fuel element industry say that larger volume of business, and the accompanying standardization and technical advances will result in the desired cost reductions. At the moment, we are stuck with this "chicken and egg" problem.

There are several ways in which the Government can act as the catalyst in breaking this impasse and starting a healthful chain reaction. First, at little or no additional expense it could fill its own requirements for enriched fuel and

fuel elements through available commercial sources instead of in Government-owned plants and laboratories. For example, the enriched metal now supplied by the Atomic Energy Commission for submarine reactors could be produced by private industry in the same facilities which are used to produce the metal required for private reactors. Such a move would certainly tend to reduce the cost of metal for private reactor operators and to strengthen the fuel industry. We believe it would be no more costly to the Government.

We believe also that a way must be found which will permit the Government to share with industry the excess costs of nuclear powerplants as compared with those using fossil fuels for a short period until the costs reduction brought about by increased volume and experience makes this no longer necessary. If a mechanism can be found to do this, so that our current rate of construction of nuclear powerplants can be increased over the next few years, we believe further Government assistance would then not be necessary. It seems to us that such an approach would result in the quickest, surest, and most economical way for this country to realize its nuclear power goals.

NEW ENGLAND ELECTRIC SYSTEM,
Boston, Mass., February 9, 1959.

Hon. CLINTON P. ANDERSON,
Joint Committee on Atomic Energy,
U.S. Capitol Building, Washington, D.C.

DEAR SENATOR ANDERSON: Thank you for your invitation to submit a statement to be included in the record of the Joint Committee's 202 hearings.

As you know, New England Electric System is deeply involved in the Yankee nuclear power project having a 30 percent share of this joint New England effort. This is being reported on separately and I shall confine my remarks to our own future plans.

New England Electric System reported to your committee last year on its plans to build a large nuclear powerplant to be completed in the mid-1960's. Neither the type of this plant nor its exact size has yet been settled finally, although we think in terms of a 200–300 megawatt unit and anticipate its being brought in as a routine addition to our integrated power system. At the present time we have a peak load of approximately 1,350 megawatts and anticipate a load of something over 2,000 megawatts by 1965. Our power sources include 550 megawatts of hydro plants and 940 megawatts of thermal plants, and we believe a nuclear plant of the size we propose can be appropriately integrated in our program to meet our expanding loads.

The exact timing of this system addition will, of course, depend somewhat on the rate of our load growth. At the present time we are engaged in problems of site selection, transmission studies, etc., and do not anticipate being forced to make a decision between competing types of plants or to settle details of pressure, temperature, etc., for another year or so.

Sincerely yours,

IRWIN L. MOORE.

(See also Yankee Atomic Electric Co. statement, p. 483.)

NORTHERN STATES POWER CO.,
Minneapolis, Minn., February 4, 1959.

Hon. CLINTON P. ANDERSON,
Joint Committee on Atomic Energy,
U.S. Capitol Building, Washington, D.C.

DEAR SENATOR ANDERSON: The following is in response to your invitation of January 27, 1959, to submit a written statement for the record of the hearings under section 202 of the Atomic Energy Act of 1954.

We submitted comments on the Joint Committee's staff report under date of October 15, 1958, a copy of which is attached. We have nothing now to add to those comments. See page 95 of "Comments of Rector Designers and Industrial Representatives on the Proposed Expanded Civilian Nuclear Power Program" (committee print, December 1958).

We are in very close agreement with the conclusions and recommendations of the Commission's ad hoc committee. We especially agree with the recommendation that increased effort be put on the fuel cycle, including fabrication.

Our own studies lead us to the belief that competitive fuel costs will be much more difficult to obtain than competitive plant construction costs.

We are in agreement also with the ad hoc committee in its recommendation of a broad general program of applied research, with a reduced emphasis on the construction of large powerplants. We thing the ad hoc committee's concept of few and carefully selected prototype plants (in the committee's definition) is excellent. It is our view that economic nuclear power will be more quickly realized if the problems of fuel and components, which are being made evident in the current demonstration program, are intensively worked on, than if efforts are scattered in the construction of a variety of large plants.

We also most heartily agree with the committee in its suggestion of greater flexibility in Government assistance in implementing the program. The present insistence on completion of construction, whether economical or not, has served its purpose, we believe in providing a measure of the design, construction, and operating problems, and also in providing the facilities within which these problems may be worked out. We ought now to concentrate on solving these problems, rather than on constructing plants.

Our Pathfinder project, scheduled for operation in 1962, is proceeding on schedule. We foresee no obstacle to completion on schedule. AEC personnel, without exception, have been cooperative and prompt in acting on requests we have made for advice or assistance.

We appreciate this opportunity to express our views to your committee.

Sincerely yours,

ALLEN S. KING.

STATEMENT BY NUCLEAR-CHICAGO CORP.

This statement is submitted at the request of the above-named committee for the purpose of commenting upon certain phases of the Atomic Energy Commission's program and activities. The information is presented under the following captions:

"1. Background for Our Comments."
"2. The Field of Education in Atomic Energy."
"3. The Atomic Energy Commission Isotope Development Program."
"4. The Need for a Healthy Instrument and Isotope Industry."
"5. Conclusion."

BACKGROUND FOR OUR COMMENTS

Our comments are limited to the fields of radioisotopes and nuclear instrumentation because the entire efforts of our company are devoted to this field and have been since the company started over 12 years ago. Others are more qualified to speak in the other areas, particularly that of reactors and power uses of atomic energy.

Today, over 95 percent of our sales are of regular commercial products which are offered in our catalog. These products were developed by our own technical division with our own funds. We have less than $75,000 of development contracts with Government agencies and only one of these, for less than $50,000 is with the Atomic Energy Commission.

The isotope and instrument industry is presently the only phase of atomic energy that can be commercially self-supporting. However, if this new tool, the isotope, is to be exploited at an accelerated rate in order to boost the technology and productivity of our country in the cold war, then assistance is required. Government assistance can cause serious problems, and in more peaceful times would not be desirable, but as citizens who can visualize the immense gains to be made by the use of the isotope tool and who are interested in the country's welfare, we advocate it. In order to help the development in this area our Mr. John L. Kuranz, vice president, has accepted an appointment to the Advisory Committee on Isotope and Radiation Development of the Atomic Energy Commission.

THE FIELD OF EDUCATION IN ATOMIC ENERGY

We firmly believe that the proper handling and support of the educational field in atomic energy offers our country one of the best areas for development and keeping ahead in this growing industry. There is a shortage of scientists and engineers and too many people feel that atomic energy is "just too complicated,

dangerous and beyond their comprehension." This is unfortunate because what people do not understand they fear, and what they fear they stay away from and do not use.

Actually this feeling is unjustified but the only answer to this problem is better informed and more effectively educated people in the area of atomic energy. Education properly done, will strip the unnecessary mystery away from this useful tool.

The lack of knowledge of the techniques of using isotopes is one of the basic reasons for the small amount of isotope utilization. It is the nonnuclear scientist and engineer, such as the chemist, the biologist, the agronomists, the mining engineers, and those in industry, who know the problems of their business who must be able to apply the isotope tool to the solution of their problems.

To demonstrate our belief in this need, we call your attention to the educational products in our catalog that we have developed with our own funds, as teaching aids. Some of these devices date back to the early years of our company.

The programs recently initiated by the Reactor Development Division, the Division of Biology and Medicine and the Division of Isotope Development whereby funds are granted to educational institutions for incorporating nuclear courses in their curriculums have already increased the courses being offered by institutions of higher learning. These programs which place the educational function of course planning and teaching in the schools are well conceived and administered.

Funds for these programs have not been sufficient to care for a large number of the requests from institutions which means that considerable expansion can take place by greater allocations, to say nothing of programs that could be originated to foster more nuclear teaching in high schools, night classes, or correspondence courses.

ISOTOPE DEVELOPMENT PROGRAM

The isotope development program of the Atomic Energy Commission is pointed toward the entire field of radioisotopes but has its heaviest emphasis in developing industrial uses. This, we believe, is fundamentally sound because the industrial uses of radioisotopes are a great and yet largely untapped reservoir of ideas for improving the country's production capacity and potential in lower costs. The surface has hardly been scratched, yet savings are substantial.

A basic reason for the small amount of isotope utilization is the lack of a good understanding by management and other industrial personnel of how isotopes can benefit them, and when properly handled, the lack of hazard associated with isotope utilization. There is much general publicity as to how isotopes save money by tool wear studies, location of leaks, gaging, etc., but information showing in detail how really simple and nonhazardous some of these applications are is not well publicized.

To demonstrate our belief in this need, we call your attention to the Gunlock Chart (exhibit A) and the technical bulletins (exhibit B) that we are currently distributing to help fill the information gap. By this literature, we try to show many uses and to show how small quantites of isotopes, that are exempt from licensing because of the nonhazardous amount, can be used. (The exhibits referred to above are on file with the Joint Committee.)

It is our understanding that the Atomic Energy Commission is now going to help in this type of information endeavor in its Isotope Development Division and again we endorse the program as an expediter of isotope utilization.

HEALTHY INDUSTRY

Unless there exists a strong isotope and instrument industry to design, manufacture, sell, and service the needs of isotope users, there will be no ready way for the users created by education and information to employ the isotope tool. For a scientific industry to be strong in its ability to consult with and help varied customers and to supply detailed information and service on its products, it is necessary that it maintain a technical staff capable of developing its products. Thus a strong industry will develop new products so that as new users appear who may have need for a product differing from an existing one, many companies will complete to fill the needs of these new users.

With each passing year, the Atomic Energy Commission is doing less product development work and the industry is doing more. The less product development work done by the Atomic Energy Commission and the more the Atomic

Energy Commission laboratories are equipped with standard equipment, the stronger will become the instrument industry.

Because the isotope and instrument industry is small, it must invest its funds in development projects that in general are short and relatively low cost so that sales can be built to higher levels that will support more costly developments. The projects become more costly when basic knowledge must be gained in addition to normal product development.

During the existence of the Atomic Energy Commission and its predecessor, the Manhattan project, a vast amount of research work has been carried on that is useful in the isotope development field. The applied research, however, was directed primarily toward military and power needs so that there is basic research which can be done which will be useful to the isotope development program.

A furtherance of the isotope tool will therefore result, if the Atomic Energy Commision were to do more basic research in fields that cannot now be afforded by the private instrument industry rather than in developing instruments.

CONCLUSION

We have tried briefly to point out how we believe the use of isotopes in industry can be accelerated by education and information, by having a healthy and profitable industry and by additional basic research. We want to emphasize that the recommendations made will not produce immediate large scale results this year or next, but that they will build a very solid future so that each succeding year will see this country gaining the benefits from the isotope tool at an accelerating pace.

The Atomic Energy Commission should be given considerable credit because those things which have been done to date to speed the use of isotopes are well conceived and are in the proper direction.

STATEMENT OF R. A. BRIGHTSEN, PRESIDENT, NUCLEAR SCIENCE AND ENGINEERING CORP.

Mr. Chairman, I am R.A. Brightsen, president of Nuclear Science & Engineering Corp. (NSEC) of Pittsburgh. My experience in the atomic energy field dates back to early 1945 when I was employed as an analytical chemist at Oak Ridge. In 1948 I participated in Project Sandstone, the atomic weapons tests in the South Pacific as a radiochemist with Tracerlab. From 1950 to 1954 I was a senior scientist in radiochemistry at the Westinghouse Atomic Power Division, where I participated in the solution of some of the radiochemical problems associated with the development and operation of the Nautilus.

In the summer of 1954 and through the assistance of Gordon Dean, NSEC was organized as an experimental research, development, and service organization, specializing in the problems and applications of radioactivity, a phenomenon which can be truly characterized as a common denominator of the atomic energy field. During the 4½ years since our inception, we have grown from a full-time staff of 5 to a present staff of approximately 60 people. During these early years, we were most fortunate in having the active guidance, as chairman of our broad of directors, of Gordon Dean, whose tragic death in August of 1958 represented a great loss to the country as well as to our company. His close associate, Eugene Zuckert, has now become chairman of our board of directors. On the scientific side, we have had overall guidance as board members from such notable figures in the world of atomic energy as Glenn Seaborg, Manson Benedict, Charles Coryell, and Truman Kohman.

Today I should like to comment on the newly established isotope development program of the AEC. This program is one which we at NSEC consider a key to rapid exploitation of the tremendous potentials of isotope applications in industry, and I should like to quote the observations made to this committee in my testimony of February 28, 1957:

"Finally we would like to observe, on the basis of our experience, that rapid exploitation by industry of nuclear (or isotope) techniques is not being achieved. This is in part due to lack of understanding on the part of industry, but more importantly due to high initial development costs which cannot be justified from a single corporation's point of view. We should like to suggest that the AEC consider an industrial applications program whereby the AEC would

partially subsidize development programs submitted by an industrial organization."

We were extremely gratified to observe the establishment of the isotope development program about 18 months later, and I should like to turn now to some comments on how we think the isotope development program can be made most effective.

During our almost 5 years of existence, it has gradually become clear that the most effective way for encouraging the use of isotopes by industry is to approach the educational and developmental problems on an industry basis. It has frequently been observed by my associates and friends that the many conferences on industrial applications of radioisotopes range over a wide variety of industries, with consequent superficial treatment of any given industry. As a result of these observations, NSEC conceived, organized and conducted the first isotope applications symposium for the pharmaceutical industry in the fall of 1958. The applications discussed were those common to the pharmaceutical industry, and the degree of interest, evidenced by attendance and subsequent initiation of programs, was gratifying.

It is our opinion that the isotope development program would be most productive if the AEC can enlist the active cooperation, both financially and technically, of industry associations such as the American Petroleum Institute, the American Iron and Steel Institute, and many others. Through this mechanism, the interest of the industry would tend to be served rather than those of a specific corporation, and the dollars appropriated for the isotope development program would therefore be used most effectively. We believe such joint programs can be successful only if such industry associations clearly can see that it is the intent of the AEC to maintain the program for a moderate period of time, perhaps of the order of 5 years. It naturally will be extremely difficult to involve such associations in this kind of an undertaking if they believe it is likely to be a 1- or 2-year endeavor. With that proviso, we should like to suggest that perhaps two types of programs be initiated.

1. Short-term development programs: Under such programs, which might be partially financed by the AEC and partially by the industry association, radioisotope and radiation applications which are known to be successful in the laboratory or other industries could be reduced to practical applications that can be immediately put to work in the research and production programs of the specific industry, using people who have relatively little background in tracer applications. Such short-term programs would have the net effect of demonstrating to the industry that isotope applications can be immediately practical and valuable in their operations.

2. Long-term programs, which again might be partially financed by the AEC and partially by the industry association. Such programs should involve intensive as well as extensive analysis of the industry to ascertain areas where radioisotopes may be of significant use. These are the so-called unborn uses of radioactivity that Commissioner Libby has referred to in the past. These long-term programs would have as a basic purpose the mapping-out of such experimental development programs as might be necessary to reduce the potential applications to practical techniques.

In addition, I should like to point out that the Atomic Industrial Forum has observed increasing interest among its members in radioisotope applications and, for that reason, is considering increased emphasis on this area from the Forum standpoint. It would seem to us highly desirable that the AEC join forces with the Atomic Industrial Forum and perhaps the appropriate industry association to sponsor a series of specific industry forums on applications of radioisotopes and radiation. This, we feel sure, would stimulate very considerable interest in isotope uses by companies of all sizes in a given industry.

We at NSEC are at present involved in several contracts under the isotope development program, and we are already engaged in discussions with some of the industry associations with a view toward stimulating their financial and technical participation in such programs. In some industries, however, there are no industry associations with the orientation necessary for such participation and in these cases, the burden of coordinating industrial interest will fall upon the staff of the AEC, as well as organizations such as our own.

We are extremely pleased by the way Dr. Aebersold and his staff have so far handled the IDP, and we believe that some of the suggestions made here would be valuable in insuring wide industrial participation and eventual elimination of AEC support for such programs. We believe that the industrial exploitation

of these techniques would grow very much more slowly were the isotope development program not in existence, for the time it takes for information to diffuse from the research laboratory in a university or Government lab to the proper industrial people is very large if there is no coordinated attempt to stimulate and educate. It seems very clear that we cannot hope to achieve maximum utilization of this tremendous tool for industry unless there is a coordinated program, with Federal direction and financial support, for a reasonable period of time. I fully agree with Dr. Libby and Chairman McCone in their evaluation of the tremendous leverage factors involved in the relatively small program that the AEC has established in this area.

In closing I should like to express my sincere appreciation for the opportunity to present to you some of our views on this specific aspect of our atomic energy program. It is our hope that these opinions and recommendations will contribute in some measure toward a vigorous partnership between the Federal Government and private industry.

PIONEER SERVICE & ENGINEERING CO.,
Chicago, Ill., February 26, 1959.

Senator CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy, Congress of the United States, Washington, D.C.

DEAR SENATOR ANDERSON: Speaking for Pioneer Service & Engineering Co., we appreciate the opportunity to present our views to be included in the record of the current hearings pursuant to section 202 of the Atomic Energy Act of 1954. Our observations will be confined to atomic power and the allied aspects of the program.

We find ourselves in accord with the broad principles and objectives of the Joint Committee's staff report and the Commission's ad hoc committee report which we believe are reconcilable. The primary emphasis in both reports on continued and expanded reactor research and development by the Atomic Energy Commission coincides very closely with our views as expressed in the statement we submitted in connection with the hearings last year. At that time we said in part as follows:

"Under the reactor demonstration program and concurrently with it, we have a very creditable number of full scale atomic powerplants under construction or committed with others in prospect. These are coming into being in keeping with the traditional and effective history of the development of electric power in this country which has made us the world leader in this field. Large sizes in plants are not necessary to produce the needed information. The electric industry in this country made its technological progress by steady developments from small beginnings. In our opinion, an accelerated program for building large scale atomic powerplants would be wasteful if it does not allow adequate time for proper evaluation and recognition of the status of the technology associated with each type. Let the construction and operation of full scale power reactors follow the presently established pattern and progress in step with the development of the necessary technical and economic information. We can do this and provide the desired leadership internationally in the doing. We are well ahead with our atomic power program on a broad front and are in a position to show other countries of the world the way as rapidly as their economies will support expansion of their electric power facilities. The 'Three Wise Men' have said as much.

"Our world position would be enhanced further by the expansion of our research and development activities. This is an area in which the Commission is appropriately organized and equipped and in which funds available for the atomic power program could be employed most productively for the good of the domestic program and the international program as well.

"We believe it is important that aid be continued as at present under the reactor demonstration program and that the national laboratories continue their present programs, but we also strongly urge a considerably broader effort with respect to atomic fuels and materials testing. The emphasis of the Commission should be directed toward the fundamental problems that contribute to the high cost of atomic power irrespective of a particular type of reactor. These include fuel technology, materials, reactor safety, chemical processing, and radioactive waste disposal. Development of better techniques, equipment, and basic information in these areas will do more than anything else to bring economic atomic power closer to reality."

These continue to be our views, and we would like to add a few additional thoughts for consideration. At this time, we would also urge that fundamental work on the design and requirements of the containment building for reactors be added to the types of research and development worthy of encouragement and financial support by the Commission. Under present requirements, this feature of a reactor plant accounts for a very substantial portion of the total plant cost. We believe it is an area in which there is a good opportunity for worthwhile reductions in plant investment.

While manufacturers of powerplant equipment and components as a regular part of their programs do a great deal of continuing research and development work, we believe that with some direct financial assistance from the Commission many would be able to do a great deal more toward the advancement of economical atomic power. In other words, some of the research and development funds provided to the Commission could be used by the equipment manufacturers to the overall advantage of the program in the area of reductions in plant investment.

It appears to us when considering the size of prototype plants, which we assume to be first generation plants, that it is important to keep in mind that 80,000 kilowatts (electrical) is a full-scale plant for a large number of electric utilities. When these utilities add a plant of that size to their systems, even at an investment substantially equivalent to the current cost of a conventional plant, they must have one that is a source of dependable power reasonably free of the uncertainties of experimentation. To us, this means that prototype plants of such a size would be out of reach for too large a segment of the utility industry to accomplish the objectives of the Joint Committee and the Commission. A maximum size of 50,000 kilowatts would be more effective as to probable industry participation and, in our judgment, large enough to give desirable technical, operating, and cost answers. Second and third generation plants in the 80,000 kilowatt-size range would be more logical.

In conclusion, we would strongly advocate an annual evaluation and review of the program by a committee such as the ad hoc committee composed of representatives of Government, industry, and research organizations. This would save a great deal of time and effort for all concerned and provide a means of correlating various views and of defining a realistic rate of progress and expenditure of time and money.

Respectfully submitted.

FRED C. KELLOGG, *President.*

STATEMENT SUBMITTED BY POWER REACTOR DEVELOPMENT CO.

(See also Detroit Edison Co. statement, p. 442.)

INTRODUCTION

This statement is submitted by Power Reactor Development Co. (PRDC) for inclusion in the record of the hearings being held by the Joint Committee on Atomic Energy during the 1st session of the 86th Congress pursuant to section 202 of the Atomic Energy Act.

PRDC is a nonprofit Michigan membership corporation. It is engaged under the Commission's power demonstration reactor program in the design and construction of, and will operate, the reactor portion of the Enrico Fermi atomic powerplant. The reactor is a developmental fast neutron power breeder reactor and the plant is located at Lagoona Beach, Monroe County, Mich. Also associated with the project are the Detroit Edison Co., which is building and will own and operate the conventional steam turbine-generator facilities which will utilize steam produced by the reactor, and Atomic Power Development Associates, Inc. (APDA), a nonprofit New York membership corporation, which is conducting important programs of research and development, including the nonnuclear test operation of full size components of the reactor.

STATUS OF CONSTRUCTION AND PROCUREMENT

Considerable construction progress has been made during the past year. The reactor vessel was delivered to the construction site in April 1958 and has been installed in the containment building. At present internal shielding is being installed in the vessel. The primary shield tank which surrounds the reactor

vessel and the secondary shield wall steel plate have also been erected. Primary sodium system piping is now being installed preparatory to operation of the nonnuclear component test facility. Sodium pump tanks and intermediate heat exchanger shells are in place. One of the pumps will be installed for use during the nonnuclear testing period. Other major items of equipment to be installed in the reactor containment building have been received at the construction site or are being fabricated.

Facilities other than the reactor containment building which are completed or nearing completion include the sodium storage and purification building and office building. The control and steam generator buildings are being erected and a 30-ton crane has been installed in the steam generator building. Foundation for the ventilation building has been poured and piping is being installed. Excavation for the fuel and repair building is now complete. Construction of the inert gas building and a health physics building is scheduled to begin about June 1, 1959.

In addition, the design of a major portion of all components and systems has been completed so that fabrication is either underway or bids are being sought. For instance, contracts for core and blanket subassemblies, for steam generators, and for instrumentation have been placed and these are being fabricated.

The estimated construction completion date of August 31, 1960, remains realistic and our experience with fabrication of the more unique components does not indicate any need to revise the schedule at this time.

PROJECT EXPENDITURES TO DATE

Schedule 1 attached to this statement provides a breakdown of expenditures in connection with the project through December 31, 1958, by the Detroit Edison Co., PRDC, and APDA. Detroit Edison has actually expended some $2,400,000, or 14.1 percent of the estimated total cost of the nonnuclear facilities; it has firmly contracted, however, for more than 60 percent of these facilities. PRDC and APDA together have expended some $10,500,000, or 25 percent of the estimated total, for equipment and construction of the nuclear portion of the plant; again more than 50 percent of the total has been firmly committed. Similarly PRDC and APDA together have expended $13,800,000 on preliminary design and research and development work. A total of some $26,700,000 has thus been expended on the project to date by the three organizations together.

ESTIMATED PROJECT COST SUMMARY

The overall cost of research, development, and construction of the Enrico Fermi atomic powerplant to be borne by PRDC, APDA, and the Detroit Edison Co., totals $78,232,000. The contract between the AEC and PRDC under the power demonstration reactor program provides that the Commission will perform certain fast reactor research and development work in Commission facilities at a cost of $4,450,000, and will waive use charges for special nuclear material estimated to amount to $3,702,600. Thus the total overall costs are $86,384,600. Schedule 2 attached to this statement presents these estimates in greater detail.

Construction cost.—The estimate of total plant construction cost of the nuclear and nonnuclear facilities (schedule 2) is $59,015,000, which is $7,934,000 in excess of the estimate of a year ago. This increase is due primarily to three items:

1. An increase of approximately $3 million in the cost of the nonnuclear turbine-generator facilities, the estimate for which was under review last year;

2. An increase of somewhat over $1 million due to the restatement of the cost to APDA of the equipment and devices to be supplied for the component test facility which will be used in the reactor and which have heretofore been arbitrarily assigned as having a value to PRDC of approximately $3 million; and

3. An increase of some $3,380,000 in the cost of fabricating core and blanket subassemblies. The increase in the cost of fabricating fuel and blanket elements, however, is partially attributable to the fact that the estimates now include the cost of purchasing two full core loadings instead of one as had previously been planned.

The Detroit Edison Co., which is engaged in building and will own and operate the nonnuclear conventional steam turbine generator is filing a statement for the record of these section 202 hearings and the attention of the committee is directed to that statement for information regarding the nonnuclear component of the total estimated project cost, which is shown in schedule 2 as $17 million.

Research and development.—The estimated total research and development costs to be borne by PRDC and APDA together amount to $19,217,000, of which $16,217,000 will be by APDA and $3 million by PRDC (schedule 2). Of this total, $13,807,000, or some 68.4 percent, had been expended by December 31, 1958 (schedule 1). The remaining $5½ million research and development expenditures are planned for 1959 and 1960.

Financing arrangements.—Reference to schedule 2 will show that the total projected cash requirements for construction, research, and development of PRDC total $40,820,000. These anticipated requirements are more than covered by firm commitments by PRDC's member companies to contribute to PRDC in the period 1956–61 the sum of $27,448,000, and by a $15 million loan to PRDC from a group of banks, all of which total $42,448,000. In addition, PRDC's member companies have executed further firm contributions commitments for the year 1962 in excess of $3½ million. The total amount of PRDC's long-term bank loan has now been taken down in accordance with the terms of the loan agreement. Repayment of the loan is guaranteed by certain PRDC member companies.

STATUS OF RESEARCH AND DEVELOPMENT

During the last year the continued operation of EBR–I and the completion of a major portion of the PRDC critical experiment on Zero Power Reactor III have provided extremely valuable information in the fast reactor field, which information is of importance to the Fermi project. The experiments on the EBR–I Mark III core have been conducted by the Argonne National Laboratory principally to obtain experimental confirmation that the instabilities exhibited in previous EBR–I core were not inherent in fast reactors. The Mark III core was designed to eliminate the fuel element bowing permitted by the previous EBR–I cores; the new core has been tested under a great variety of operating conditions and has exhibited no instability whatsoever. Thus, by demonstrating absence of any instability, the Mark III experiments have now dispelled any doubt which may have remained as to the inherent stability and safety of fast reactor systems. Moreover, the tests appear to have experimentally confirmed that bowing was the prime source of instability in the previous cores. Based on principles of mechanical rigidity comparable to those of the EBR–I Mark III, PRDC has perfected and satisfactorily tested a core design for the Enrico Fermi reactor which will prevent bowing. The significance of the EBR–I experiments was expressed as follows in a paper prepared by the members of the Argonne National Laboratory EBR–I research group and presented at the 1958 Geneva Conference on Peaceful Uses of Atomic Energy:

"* * * it appears certain that the prompt positive coefficient of reactivity has been eliminated from EBR, or at least made inconsequential by a design which eliminates rod bowing (p. 21). * * * It is now evident that the instability in the EBR–I, Mark I and II, was not a function of the neutron energy and hence not peculiar to fast reactors (pp. 25–26)." (Paper No. 1845, International Conference, Geneva, Switzerland (1958).)

At the same time that the EBR–I Mark III tests have been conducted, the critical experiment on the core configuration for the Enrico Fermi reactor has been going forward. It is now about half completed and should be finished within the year. These experiments, which have been conducted on Zero Power Reactor III, are designed to ascertain a great variety of reactor operating parameters for the purpose both of finalizing such matters necessary for component fabrication as core enrichment and control rod worth and of predicting in general the nuclear characteristics and behavior of the reactor. Preliminary analysis of the data obtained in the critical experiment indicates that the reactor will have temperature and power coefficients of reactivity of the proper magnitude and sign necessary to provide stability.

As with any large reactor of whatever type, however, the indicated operating characteristics of the Enrico Fermi reactor will be exhaustively analyzed and confirmed in low power test operations before full power operation is begun. A full year of such low load testing is planned. In this connection it is gratifying to note that oscillator tests, which provide the principal technique used in testing of fast reactors and which is planned for extensive use in the testing of the Enrico Fermi reactor, were used extensively on the EBR–I Mark III and safely and reliably confirmed its stability characteristics.

In addition to the commission sponsored EBR–I operation and critical experiment, continuing programs of research and development on containment, reactor simulation and other aspects of the project have been conducted dur-

ing the year and have been coordinated with design, fabrication, and erection of components.

In cooperation with PRDC and APDA, the commission has undertaken a substantial program of fast reactor fuel development. It is believed that this program will develop information which will be of very considerable long-range importance in the field of fast reactor technology.

During the year PRDC entered into an agreement with the United Kingdom Atomic Energy Authority for the exchange of information in the fast reactor field. Project engineers have already visited Dounreay and others will be present during startup of the Dounreay fast breeder reactor later this year.

PERSONNEL TRAINING

Assignments of certain key operating personnel for the nuclear portion of the plant have been made and their training has been initiated. The training program includes onsite training, formal study, inspection of existing reactor facilities and on-the-job training at commission installations. Engineers are enrolled in the 6-month Shippingport course and have received experience at the National Reactor Testing Station, the Sodium Reactor Experiment, and at the Commission's Savannah River plant.

CONSTRUCTION PERMIT PROCEEDINGS

On December 10, 1958, the Atomic Energy Commission issued its opinion and initial decision in the PRDC construction permit proceedings. The commission found that there was "reasonable assurance" that a reactor of the general type proposed by PRDC "can be constructed and will be able to be operated at the location proposed without undue risk to the health and safety of the public," and that PRDC was technically and financially qualified to construct the proposed plant. The Commission's order continued in effect PRDC's construction permit, with certain modifications which had been recommended by the AEC separated staff and to which PRDC did not object. The order further provides for continuing review by the Commission of the safety characteristics of the proposed reactor, and for further proceedings prior to issuance of an operating license. In connection with this continuing review, PRDC is to file quarterly technical reports and semiannual financial reports. The first such quarterly technical report will be filed early in March 1959.

As permitted by the Commission's regulations, the intervening unions have filed exceptions to the opinion and initial decision. No exceptions were filed by the State of Michigan, which had also intervened, by the Commission's separated staff, or by PRDC. The separated staff and PRDC have each filed briefs answering the exceptions to the decision which were filed by the intervenors, and the matter is pending before the Commission.

CONCLUSION

The Enrico Fermi Atomic Powerplant project is progressing satisfactorily, and those participating in it are pleased to be able to take part in the development of a type of reactor which, as said in the recent report of the Commission's ad hoc committee, is vital to the long-term economic use of our uranium reserves.

Respectfully submitted.

POWER REACTOR DEVELOPMENT CO.,
By WALKER L. CISLER, *President.*

SCHEDULE 1.—*Enrico Fermi plant expenditures to date by the Detroit Edison Co., Power Reactor Development Co., Atomic Power Development Associates, Inc.*

	Expenditures through Dec. 31, 1958	Estimated total cost	Percent expended
Nonnuclear portion of plant: Plant expenditures by the Detroit Edison Co	$2,406,021	$17,000,000	14.1
Nuclear portion of plant:			
Expenditures by PRDC:			
Direct plant expenditures [1]	5,144,660		
Fuel element fabrication expenditures [2]	381,715		
Other construction and test expenditures [3]	2,492,121		
Direct plant expenditures by APDA [4]	2,483,000		
Subtotal	10,501,496	42,015,000	25.0
Research and development:			
Expenditures by PRDC	670,444		
Expenditures by APDA of benefit to Fermi plant [5]	13,137,000		
Subtotal	13,807,444	19,217,000	68.4
Total	26,714,961	78,232,000	34.1

[1] Not including expenditures on fabrication of fuel and blanket elements.
[2] This covers initial expenditures on contracts for the fabrication of 1 complete blanket and 2 complete core loadings.
[3] This includes all indirect plant construction costs with the exception of research and development expenses, which are separately listed. Included herein are expenditures for interest, taxes, insurance, administrative, and overhead.
[4] This covers expenditures by APDA allocable to the purchase and installation of equipment which will be transferred to PRDC after nonnuclear testing and which will be incorporated into the nuclear portion of the plant.
[5] This includes those research and development and administrative expenses of APDA from 1952 through 1958 which have been of benefit to the Fermi project.

SCHEDULE 2.—*Estimated overall cost summary—Enrico Fermi plant*

	PRDC	APDA	Detroit Edison	Total
Nonnuclear portion of plant:				
Site and development			$1,210,000	$1,210,000
Structures and equipment			15,590,000	15,590,000
Interest during construction			200,000	200,000
Subtotal			17,000,000	17,000,000
Nuclear portion of plant:				
Direct and indirect plant costs [1]	$33,440,000	[2] $4,195,000		37,635,000
Fuel element fabrication [3]	4,380,000			4,380,000
Subtotal	37,820,000	[2] 4,195,000		42,015,000
Total nuclear and nonnuclear plant costs	37,820,000	4,195,000	17,000,000	59,015,000
Research and development by APDA-PRDC:				
Actual (1952–58)	670,444	13,137,000		13,807,444
Estimated (1959–61)	2,329,556	[4] 3,080,000		5,409,556
Subtotal	3,000,000	16,217,000		19,217,000
Total	40,820,000	20,412,000	17,000,000	78,232,000
Research and development work by AEC in commission facilities				4,450,000
Use charges to be waived by AEC to Aug. 31, 1965				[5] 3,702,600
Total				8,152,600
Total overall costs				86,384,600

[1] This includes all direct and indirect plant construction and nuclear testing costs with the exception of fuel element fabrication and research and development, listed separately herein. Included herein are interest, taxes, insurance, employee training, administrative and overhead expenses, and all costs of operation during a nuclear test period of a full year, which test period is scheduled for September 1, 1960–August 31, 1961.

[2] APDA is purchasing and installing certain equipment and devices which, after nonnuclear testing by APDA, will be transferred to PRDC and incorporated into the reactor plant. These components are estimated to cost APDA $4,250,000. Upon transfer to PRDC, however, PRDC will pay APDA the sum of $55,000, estimated to be the salvage value of these components. This payment has been included in PRDC's direct and indirect plant costs. The net cost to APDA of these components, after crediting the payment to be received from PRDC, is accordingly estimated at $4,195,000.

[3] This includes fabrication costs for not only the initial core and blanket loading, but for a second complete core leading as well.

[4] This includes APDA research and development work and administrative expenses, including material and supplies required for the nonnuclear testing but not incorporated into the permanent reactor plant, for the year 1959 only. Since substantial work of benefit to the project will also be done by APDA subsequent to 1959, this represents a minimum estimated figure.

[5] By the terms of the AEC–PRDC contract effective January 1, 1957, use charges for special nuclear material are waived for the period ending 5 years after the date of PRDC's facility license. On the basis of its present schedule, this date would be August 31, 1960, so that the waiver period would terminate August 31, 1965.

REPUBLIC AVIATION CORP.,
Farmingdale, Long Island, N.Y., February 16, 1959.

HON. CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy,
Capitol Building, Washington, D.C.

DEAR MR. ANDERSON: I appreciate receiving your invitation to appear before the Joint Committee on Atomic Energy at the forthcoming hearings and the opportunity to furnish the committee with information concerning the development, growth, and future of the atomic energy industry. I feel certain the committee's hearings this year will establish the need for the United States to maintain its dominant role in the development and application of atomic energy and further define and clarify the objectives of our national atomic program. I believe the need to achieve more rapid progress in its development has become apparent to everyone, and the committee's hearings should certainly provide a useful forum for accomplishing this purpose.

Atomic energy is a part of the future business environment of Republic Aviation Corp. Republic's interest in nuclear reactors has been stimulated by its activities and interests associated with military and space systems. Active participation in reactor projects will assist Republic in the future development of

nuclear-powered aircraft, missiles, rockets, space vehicles and auxiliary nuclear power sources. Republic recently initiated the most comprehensive research and development program in its history, including a substantial investment over the next few years in astronautical research. Among the growing nuclear activities at Republic is the theoretical and experimental program to develop a plasma propulsion system for space travel, embodying a reactor power source. The research and development personnel are engaged in design studies of nuclear powered aircraft and nuclear discrimination methods for an anti-ICBM. The nuclear staff has made a technical and economic feasibility study for the construction and operation of a large, privately financed, engineering test reactor facility similar to the commission's engineering test reactor at Idaho. This test reactor project is in support of the Nation's programs for the development of nuclear power, propulsion, and materials.

In reviewing the two reports on civilian nuclear power by the ad hoc advisory committee and the Joint Committee's staff on which you have invited comment, I want particularly to urge support of the recommendations of both reports directed toward fortifying the leadership of the United States in the technology of nuclear power through the adoption of a broad program of basic research and development. It is principally in this area of the program that Republic has a primary interest and will directly participate. Because of the keen international competition that has developed in the nuclear field and the significant effect it may impose on our future, I feel that the adoption of an accelerated research program is essential to the United States. It is my hope that the committee's work will furnish the guidance necessary to enlarge the activities of private industry in the atomic energy field and support the Government in its efforts to assume responsibility for vigorous leadership and administration of the nuclear program.

Very truly yours,

MUNDY I. PEALE.

RURAL COOPERATIVE POWER ASSOCIATION,
Elk River, Minn., February 16, 1959.

Mr. CLINTON P. ANDERSON,
Congress of the United States,
Joint Committee on Atomic Energy,
Washington, D.C.

DEAR MR. ANDERSON: Thank you for the opportunity you have given us to testify before your committee on the 202 hearings. This finds our organization at a time when it is difficult for me to appear or to send a representative. Our staff is presently buried in the details of installing the turboelectric facilities which are a part of our atomic plant programs.

I should like to state; however, that we find general agreement in the ad hoc report and also the more detailed summary of the Joint Committee insofar as recommended planning and programing are concerned. Generally, we would subscribe to a program whereby the smaller first generation units are built by the Government to be operated by the smaller electric utilities, municipalities, and cooperatives, and as these plans are improved and larger capacities are put under construction by the larger utilities, that Government aid be available in technical know-how for financing the proportions of both, established in a fair manner by your committee after reviewing the requirements and problems.

If we are to obtain our prestige position rapidly in the art of atomic powerplants, then controversy between public and private power must, for the goals to be attained, be completely avoided and recognize the problems of both groups as requiring the solutions. Large companies who need large units are wasting their money building too small so a combination of Government and utility funds is needed for the large unit programs. Small organizations like ourselves and many others who are extremely capable and desirous of participating cannot afford experimental money in this program but with Government financing I am sure can contribute substantially in helping to finance these small programs by the purchase of energy.

If we review the past, I would say personally that the Joint Committee and their enthusiasm has been a strong moving force in the development of these

goals and our progress toward them. It was so in the case of rural cooperative power and we sincerely appreciated the committee's actions. We trust your sense of urgency can be communicated to the administrating department and that there will be a stronger sense of energy generated therein for these accomplishments.

Thanking you again for your kind invitation, I remain

Sincerely yours,

O. N. GRAVGAARD, *President.*

SANDERSON & PORTER,
February 18, 1959.

Reference: Record statement for 202 hearings.

JOINT COMMITTEE ON ATOMIC ENERGY,
Congress of the United States,
U.S. Capitol Building,
Washington, D.C.
(Attention: Mr. George F. Murphy, Jr.)

GENTLEMEN: During the past months your committee has been examining the nuclear power program in this country and have established as an overall objective the reduction of the cost of nuclear power to a point where it will be competitive with power as obtained from fossil fuel sources, in some areas, in 10 years.

It is recognized that for the present and immediate future the availability of fossil fuel is not critical and, except in some limited areas, its cost is substantially less than nuclear fuel costs for several years to come. Therefore, if we are to achieve this objective, great care must must be taken at this time in selecting the type plants which after the expenditure of our development moneys will be economically attractive.

The Tommaro-Smyth Ad Hoc Committee report, which was recently prepared for your guidance, makes certain recommendations regarding reactors and reactor types that should receive further emphasis in development. Among these was the pebble bed reactor which has been under development by Sanderson & Porter for the Commission for the past year. We would like to take this opportunity to summarize the background of this development and some of the salient features of the system in order that you may be made fully aware of the progress made in the high-temperature, gas-cooled reactor field under Commission sponsorship.

As background information, this reactor concept was developed by Sanderson & Porter and Alco Products, Inc., with the primary objective of achieving a nuclear power system capable of operating at a temperature which would permit the production of steam suitable for use in modern steam turbine equipment, and using a fuel which could be fabricated, handled, and reprocessed in an economical manner. The pebble bed reactor; a high-temperature, gas-cycle system, using fuel in a ceramic form dispersed in a spherical graphite matrix, meets these requirements.

This system was brought to the attention of the Commission in 1957 and subsequently contracts were placed with Sanderson & Porter for a design and feasibility study of a pebble bed reactor-steam powerplant and the development of its fuel system.

The characteristics of this reactor system are such that it is well suited to the Thorium U^{233} breeding cycle and our efforts have been directed along these lines. Based on the presently accepted nuclear characteristics of U^{233}, the pebble bed reactor breeds as much fuel as it consumes. We recognize that some uncertainty still exists regarding these characteristics and improved experiments are being conducted in AEC laboratories to resolve the uncertainties in these fundamental data which are common to all reactors. Until this work is finished and in fact until a reactor system of this particular geometry is built, we will not know whether the system as presently designed will breed or simply have a high conversion ratio. What is clear is that in either case a pebble bed reactor-steam powerplant of 125 eMW output is capable of producing power competitive with that produced from fossil fuel-fired plants in the low-cost fuel areas of the United States.

Briefly, our studies indicate that such a powerplant would have the following characteristics:

Net electrical output: 125 eMW.
Steam conditions: 1,450 lbs./1,000° F.
Net station heat rate: 9160 B.t.u./kw-hr.
Reactor heat output: 336 tMW.
Coolant: Helium.
System pressure: 965 p.s.i.a.
Reactor outlet temperature: 1,250° F.
Fissile material: U^{233}.
Permanent inventory: 142 Kg.
Fertile material: Th^{232}.
Annual consumption (ThO_2): 155 Kg.
Estimated capital cost: $31,950,000.
$/kw net output: 256.
Fuel cycle costs: 14¢/MM Btu.
Production costs: 7.6 mills/kw hr.

Fuel elements as used in this reactor consist of graphite spheres containing fissile and/or fertile material, randomly packed in a reactor bed. This is a material form and fuel arrangement that is intermediate between the carefully fabricated, precisely located and firmly supported rods, tubes and plates used in most heterogeneous reactors and the completely unfinished and dispersed materials used in a fluid fuel reactor. Incorporation of the fissile and fertile material in graphite, from which the heat is removed by helium, permits operation at high temperature, thereby accomplishing one of the basic objectives of the design.

The composition and form of this fuel offer a comparatively simple method of fabrication which can be effected by mass production methods. Weight loading or distribution of fissile and fertile material within fuel elements is not critical and these elements can be likened to coal briquets as far as requirements for dimensional accuracy are concerned. Remote fabrication is entirely feasible, thus making it possible to handle partially decontaminated fuel. Fuel in this form is amenable to simple handling techniques in loading and unloading, thus making continuous loading with simple equipment possible. While use of these simple unclad fuel elements will result in economies in fabrication, as well as head-end treatment prior to reprocessing, and will permit a high burnup, it will allow gaseous fission products to diffuse into the gas stream. The expected activity in the primary loop is somewhere between that in the primary system of a pressurized water reactor and a fluid fuel reactor. The development of methods of decontaminating the system to ease maintenance is one of the major problems of this reactor concept and is one that is common to all high temperature reactor systems.

The limited amount of fuel element development that has been done to date indicates that there is no problem in fabricating fuel elements that will meet the mechanical requirements. Also tests indicate that there is no degradation of the structural properties of the fuel after irradiation to a burnup of approximately 12,000 MW days per ton of contained uranium. This is about 20 percent of our goal and irradiations at higher burnups are planned.

The major development problem of this fuel system concerns the absence of cladding on the fuel elements. Tests are in progress to determine the quantity and species of fission products which will diffuse from the fuel elements, and various types of ceramic coatings designed to retain fission products within the fuel elements are being evaluated. In addition, studies are being undertaken of new and novel means of removing these fission products which do diffuse into the gas stream. If we are successful in developing these methods to the point where the fission product concentration in the gas stream is reduced appreciably, the necessity for remote or delayed maintenance will have been eliminated and fuel element life will be extended.

In summary, we believe this reactor system incorporates basic design concepts whose use will eventually lead to a nuclear powerplant which can compete with its fossil fuel fired counterpart. These concepts are: high temperature operation and the use of a spherical uranium graphite fuel system which offers economies in fabrication, handling and reprocessing. At the present rate of development, it should be possible to construct a prototype plant within the next 5 years.

Very truly yours,

SANDERSON & PORTER.

SOUTHWEST ATOMIC ENERGY ASSOCIATES,
Little Rock, Ark., February 18, 1959.

JOINT COMMITTEE ON ATOMIC ENERGY,
Congress of the United States,
Room F–88, U.S. Capitol Building,
Washington, D.C.
(Attention: Senator Clinton P. Anderson, Chairman.)

GENTLEMEN: Last year I appeared before your committee and told you about the research and development project of the Southwest Atomic Energy Associates. We are an association of 15 companies:

Arkansas-Missouri Power Co.
Arkansas Power & Light Co.
Central Louisiana Electric Co., Inc.
The Empire District Electric Co.
Gulf States Utilities Co.
Kansas Gas & Electric Co.
Louisiana Power & Light Co.
Mississippi Power & Light Co.
Missouri Public Service Co.
New Orleans Public Service, Inc.
Oklahoma Gas & Electric Co.
Public Service Co. of Oklahoma
Southwestern Electric Power Co.
The Kansas Power & Light Co.
Western Light & Telephone Co., Inc.

We have a contract with Atomics International Division of North American Aviation, Inc., to carry on research and development and to perform a critical experiment for us, costing $5,354,000, all of which cost shall be borne by our members. This work is to prove up the feasibility of an advanced epithermal thorium reactor utilizing U–223 for fuel.

Our project has been underway for more than a year, and good progress was made on the physics studies. However, last October we were forced to slow down the work being performed by our contractor and may have to stop it completely. Before entering into our contract with Atomics International we wrote to the Atomic Energy Commission advising them of our proposed work and requesting 50 kilograms of U–233 with which to carry on the critical experiment. The AEC answered, saying our project was worthwhile and that we would be given an answer as to whether or not the required U–233 would be made available to us. To date, we have not received that answer.

The delay is disappointing, but has in no way reduced the attractiveness of the U–233 thorium cycle that we hope to prove up. We believe our project has great promise, and as soon as we receive an answer from the AEC—assuming that it is favorable—we shall reschedule the work on our contract with the Atomics International Division of North American Aviation, Inc.

I hope to be able to report next year that work on our critical experiment is underway and that we have some results to confirm the physics studies that have been made.

Yours sincerely,

J. ROBERT WELSH,
President, Southwest Atomic Energy Associates.

STATEMENT OF DR. LEE L. DAVENPORT, PRESIDENT, SYLVANIA-CORNING NUCLEAR CORPORATION

First of all, I want to thank you for the opportunity that you have given to us to submit once again our comments, pursuant to section 202 of the Atomic Energy Act, on the development, growth and state of our atomic energy industry. In reviewing the comments which we have submitted in past years, it is gratifying to observe the conscientious attention which has been given to the problems indicated by ourselves and others in the industry. The prompt and efficacious manner in which domestic third party liability problems have been resolved by the Anderson-Price amendment and the Commission's implementation thereof is but one example of the conscientious attention which the Joint Committee and the Commission have given to the problems of our industry. Equally significant

is the manner in which the Joint Committee and the Commission have responded to the agreed-upon need for defining specific objectives for the nuclear reactor power development program. It is primarily to the manner in which those objectives are to be accomplished that I wish to direct this statement.

It is my understanding that the now generally accepted objectives of our nuclear power program may be stated in summary as follows:

1. To develop nuclear powerplants which will be economically competitive in this country, without governmental assistance, within 10 years and abroad within a somewhat shorter time.

2. In the course of accomplishing the first objective, to share with our allies and the free world the practical peacetime benefits of such developments and in so doing to demonstrate to the entire world the efficacy and resourcefulness of our own free enterprise system; this in turn would tend to fortify the leadership position of the United States in the eyes of the world, particularly in the peaceful application of atomic energy to power.

In proposing specific methods for achieving these objectives, there has been, to our mind, increasing and somewhat disquieting emphasis on the need for increased governmental direction and control over the nuclear power program. The failure of the reactor development program to make greater headway in the last few years has been frequently cited as one example of the consequences flowing from lack of firmer and more detailed governmental supervision.

In my past statements before this committee I have emphasized my own firm conviction as to the signal success which can be achieved by private enterprise freely competing in a democratic society. However, the history of our free enterprise system has indicated the vital need for economic incentive to fuel the successful development of any given industry. Such economic incentive will normally arise from market demand for new products and increased industrial efficiency. However, supervening national objectives have occasionally required the development of a new industry more rapidly than it would normally respond to initial market demand. Thus the opening of the West necessitated an accelerated development of the nation's railroads. In the incipient stages of such industries vital to the Nation's overall welfare, the Government has frequently played a significant role in providing temporary incentive to private industrial development which might otherwise be more slowly forthcoming. However, in this country the role of our Government in such circumstances has always been regarded as a temporary expedient to be formulated and pursued as closely as possible within the traditional framework of our free enterprise system. The history of other less fortunate countries, and most recently the history of countries behind the Iron Curtain, have indicated the tragic consequences that can result from government going beyond this role and into a role of detailed and more permanent supervision and control. Indeed, the very essence of the objectives which we have set for our nuclear power program is to demonstrate the relative virtues and efficacy of our free enterprise system in the face of its most severe challenge from the controlled economies of Communist-dominated countries. It would be a rather futile victory if we were to achieve economic nuclear power at the expense of the very institutions which we are seeking to protect and the success of which we are seeking to demonstrate.

In view of the abundant natural resources with which our country is endowed, it appears clear that the normal incentives of market demand are not now present in the nuclear power industry and will probably not be forthcoming within the next 5 to 10 years. I strongly believe that what little economic incentive presently exists to immediate nuclear power development in this country will in fact be reduced still further by any increase in governmental supervision or control at this time. What is most needed in our power development program is not increased governmental supervision and control but rather increased provision for economic incentive to further private development. While Congress and the Commission have made several laudatory efforts to provide a vehicle for a successful power development program, I feel that no true effort has been made to provide substantial incentives to use of this vehicle. To this end, I have indicated several times in the past in submissions to the Joint Committee our ideas as to what form such incentives might best take. To summarize one principal area covered in my testimony before this committee last year at this time, I proposed a program which would leave decisions as to the types of reactors to be built to participating companies with specific tax incentives provided for the achievement of established goals set

forth in terms of costs per kilowatt and of installed capacity and costs per kilowatt hour. As indicated in my prior suggestions, such a program would require the participating companies to risk their own funds if such goals are not achieved thus utilizing the processes of selectivity normally inherent in freely competitive industry.

Another area in which we feel there is a vital need for development of increased incentive is the area of patents. As I have suggested in past testimony, this is an area which has traditionally provided a forceful incentive to the initiation and development of new products and industry in our country. In our own industry, in which normal economic incentives are currently absent, the patent incentive takes on added significance. However, despite the agreed-upon need for acceleration of the nuclear power program, present policy pursuant to section 152 of the Atomic Energy Act of 1954 offers little, if any, patent incentive to American industry at home or abroad.

Section 152 of the Atomic Energy Act still provides that the Commission shall retain all patent rights to discoveries and inventions made or conceived under any contract, subcontract, arrangement or other relationship with the Commission regardless of whether Commission funds are involved. While this section permits a waiver of the Commission's rights, general waivers by the Commission of its patent rights have in fact been confined to limited areas such as inventions resulting from access agreements or facility licenses. Beyond this, Commission patent policy has been stated to be one of making licenses under its patents generally available to the industry on a nonexclusive royalty-free basis and consistent with security requirements. In addition to similar nonexclusive rights in the non-atomic-energy field (the "outfield") frequently granted directly to Commission contractors for practice of the contractors' inventions, the Commission in very few cases, may grant directly to a contractor exclusive rights in the "outfield" against all but the Government, together with nonexclusive rights in the atomic field (the "infield").

Such nonexclusive rights as the Commission offers generally to the entire industry may serve to make new techniques and know-how more widely available. However, any company, particularly in the absence of other economic incentive, would obviously be loath to spend its own funds on an original development or subsequent commercial exploitation of an invention that its competitors may freely copy.

Furthermore, the great preponderance of all work in our industry in the past has involved some degree of relationship with the Commission. Thus, in view of section 152 of the act and the policies developed pursuant thereto, the area for private patent development has been extremely limited. Under these policies patent incentive has been lacking even in such areas as fixed price production contracts with the Commission under which industry in this still new, experimental and highly competitive field, has operated at great financial risk and frequently at considerable financial loss.

Under virtually all present proposals for acceleration of the domestic power program continued close relationships with the Commission, financial or otherwise, may be anticipated. If the present patent policies are to be continued, the obvious resulting limitations on patent incentive may militate against the very objectives of any such domestic acceleration program.

The absence of a workable patent program is also extremely damaging to American prestige and commercial opportunity abroad.

There appears to be a real possibility that nuclear power will soon be economically feasible in many foreign countries. In this background foreign governments have pursued an aggressive program of encouraging development and exploitation of patents in the nuclear field. Under the laws of many foreign countries private companies are permitted to and in fact have developed and are now exploiting impressive patent portfolios.

Our own Atomic Energy Commission may permit individual companies to file patent applications abroad on inventions developed in the course of any relationship with the Commission. However, this procedure may only be pursued subject to the proprietary rights of the Commission. The bilateral agreement program in turn protects such patent rights as the Commission may have abroad. From the point of view of American industry all of the foregoing merely serves to protect Commission licensees under such patents against infringement claims by third parties. However, the protection thus afforded to American companies abroad may be obtained less expensively by simple publication without the necessity for expensive patent filings.

In any event, neither Commission-held foreign patents nor the bilaterals provide American industry with any of the positive marketing and negotiating advantages normally associated with a proprietary patent position. Indeed, foreign companies obtaining, pursuant to bilateral agreements, information developed by American companies, may be in a position in some instances to file for patents in their own countries on the basis of such information and subsequently enforce such patents against American companies.

Recognizing the problems with which American industry has been faced particularly in its efforts to engage in marketing or other arrangements abroad, the Commission had begun to liberalize its attitude toward patent filings in foreign countries. Unfortunately, however, there have already been indications that the recent enactment of the National Aeronautics and Space Act of 1958, with its all-encompassing provisions for Government ownership of patents developed in that field, has given the Commission pause in its liberalized program. At this point, therefore, there is a vital need for a clear-cut expression of legislative policy with respect to development and ownership of patents in the nuclear field. In this respect, it should be noted that the discouraging patent situation in the atomic energy field was, a least until passage of the National Aeronautics and Space Act, unique not only in all fields of commercial enterprise but also in the areas of other Government contract work.

Recognizing the legitimate interest of the Government in any inventions developed pursuant to Government contracts or through use of governmental funds, we would propose that legislation be enacted which would provide for a policy similar to that presently followed by the Defense Department. Under Defense Department contracts, the contractor normally retains full proprietary rights to all patents developed. The public interest in the expenditure of governmental funds has been amply protected by the grant of a nonexclusive, royalty-free license to the Government for governmental purposes under all inventions developed under the contract. Perhaps even more significant service is rendered to the public interest by the added incentive which is by the Defense Department's policies to investment of private funds in development and exploitation of new processes and techniques valuable to the Government in its defense efforts. This Defense Department system has provided a proven example of policies sufficiently flexible to reap the benefits of competitive enterprise in times of peace without sacrificing the need for an easily expandable system to meet the needs of unforeseen crises.

One final point is perhaps deserving of mention in connection with the above comments on the patent program. It has been stated that the avowed purpose of chapter 13 of the Atomic Energy Act of 1954 and the Commission's policies pursuant thereto has been to protect the smaller companies against the predatory patent policies of larger companies. It has been suggested that these companies in turn may have developed a substantial part of their patent position with the help of Government funds. There may in fact have been some logic to this argument at the beginning of the development of our industry when virtually all work was concentrated in and through the Government. This logic, however, becomes increasingly thin with incerased investment of private funds in the development of nuclear power and the indicated goal of accelerated private development of our industry. Furthermore, in the absence of normal short-range economic incentives in our own industry, the additional absence of normal patent incentives has probably worked a greater hardship on smaller companies than on larger competitors. Traditionally small companies have looked to the development of one or more significant patents with which to effectively compete with the often overwhelmingly large portfolios of larger companies. Smaller companies have been unable to develop such significant patents and their existence and continued business success have been threatened. The antitrust laws provide effective and timely remedies for smaller companies against unreasonable patent and other restraints. The larger companies are presumably in a better position to indefinitely subsidize their participation in this industry even in the absence of immediate economic incentives. For similar reasons they are also in the best position to develop patent rights under the 1954 Atomic Energy Act through the use of private funds. It is relatively small business with limited financial resources that must be provided with some short-range incentives if it is to survive. By the same token, in the absence of normal economic incentives of a nongovernmental enterprise it is the relatively small company which is most dependent for its survival upon the fruits, patent and otherwise, of its Government contracts.

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A third area which I have indicated in the past is in need for review and attention if incentive is to be provided to increased private participation is the area of the Atomic Energy Commission's procurement practices. We have been particularly gratified in this respect at the cooperative attitude which the Commission has indicated in the past year toward consultation with the industry in this area and toward publication of their procedures and policies. We sincerely hope and believe that in light of the expressed objectives of the power development program as well as the immediate contract objectives of the Government, the Commission will continue this consultation with the industry with a view to developing improved procedures and policies published and available to all and uniformly applied in similar circumstances.

Still another area which I believe is in need of immediate attention in the interests of providing further incentive to achievement of the acknowledged objectives is the area of fuel reprocessing. I believe that it is generally agreed that reduction of the fuel cycle cost is essential to the early achievement of economic nuclear power. In turn, there will not be substantial disagreement that reprocessing costs are a vital factor in reduction of the overall fuel cycle cost. Again we are gratified at recent indications of Commission interest and support for research and development in this area. It is our feeling, however, that if the objective of competitive nuclear power within the next 10 years is to be achieved, there may be a need for a carefully planned fuel reprocessing program of much of the same type that we have already proposed for reactor development itself. Again, we would suggest the desirability of establishing cost goals and then providing incentives, tax or otherwise, for the achievement of these goals by private industry.

In this same area and until the establishment of commercial reprocessing facilities becomes feasible, initial steps may be taken by some companies to facilitate further expansion and development of their fuel element programs by undertaking major services in connection with the supply and subsequent disposition of fuel elements. Thus a company such as Sylcor might well agree to undertake to arrange for the reprocessing of fuel elements which we sell. However, until we are able to construct and develop our own facility we will have to contract with the Commission for the actual reprocessing of these elements. Section 161(m) of the 1954 Atomic Energy Act permits the Commission to enter into long-range contracts in connection with actual facility licenses issued under section 103 and 104 of the act. Unfortunately, however, it does not now permit the Commission to enter into such long-term contracts with a company such as ours which does not yet have an actual facility but seeks to undertake responsibility to the customer for a complete packaging service including reprocessing. Pending the initiation and successful conclusion of a program for accelerating private commercial reprocessing development and in the interests of encouraging further initial private participation in this field we would strongly recommend revision of the present section of 161(m) of the act to authorize the Commission to enter into long-term contracts with any person, firm, or corporation seeking to undertake responsibility to its customers for reprocessing services irrespective of whether such party itself has a production or utilization facility.

The foregoing are a few of the most vital areas which I believe call for immediate attention if incentive to private participation in nuclear power development is to be increased. If I may sum up, I would express my complete agreement with the objectives which have been indicated for a nuclear power development program. It is our hope, however, that in seeking to achieve the objective of early economic nuclear power we will not lose sight of the reason for establishing that objective; that, by holding governmental supervision and control to a minimum, and normal economic incentives to a maximum supplemented perhaps by temporary additional incentives provided by the Government, we will in fact utilize and thereby demonstrate to the fullest extent possible the inherent strength and advantages of our free enterprise system.

Résumé of Opinions Concerning Delays in the Field of Atomic Energy, Submitted by the Wedin Corp.

In the capacity of producing component parts for atomic reactors for several years directly for Westinghouse, and also for Westinghouse subcontractors, the writer has been in very close contact with the progress of our atomic program.

Basing my observations on direct personal experience and experience with a multitude of plants engaged in manufacturing, I have arrived at the following conclusions.

I also wish to make it clear that the conclusions can very easily be confirmed and substantiated by the Joint Committee on Atomic Energy if so desired.

The Atomic Energy Commission through the years has failed to realize that with the scientific breakthrough in the harnessing of the power of the atom, it has passed the infant stage and has become a grownup science in its own right. It has advanced from a superficial fact to a practical reality and can no longer be treated like a "baby in a nursery."

Through arrangements made in the early days of its history, the congressional committee, not thoroughly familiar with the Westinghouse Corp., became the local source for reactor construction, under the official supervision of the Atomic Energy Commission.

This arrangement has now developed into a parallel of a monopoly, strangling our outside know-how from contributing to the wealth of knowledge. The Atomic Division of the Westinghouse Corp. has, by its uncontrolled, bureaucratic internal composition, become the sole judge of atomic progress.

In the analysis of its composition and operation, you will find a grossly unbalanced relationship between the strictly scientific and strictly practical phases of reactor construction. It is a clearly worded example of the scientists overstepping the boundaries of their functions, neutralizing the technical and practical functions. It is a rubber stamp.

I have no "ax to grind" with the scientists. On the contrary, I have a great deal of respect for their patient and dedicated efforts in discovering new basic laws of nature on which foundation our atomic program is built. What I strongly object to is their insistent contraction of the technical and manufacturing construction beyond the prototype stage.

Anyone with technical and manufacturing experience can take a look at the Westinghouse drawing and detect the lack of sound engineering and the tremendous waste of money in its construction. I can, without hesitation, state that a reactor can be built at 30 to 40 percent of the present cost if the final design was left to practical engineers. This cost reduction is not including surplus management which has been created inside the Westinghouse Atomic Division through the cost-plus system. In this natural climate for breeding, red tape and reports have exceeded all reasonable concepts.

In the shadow of the Westinghouse operation, you will find the package for the contractors who build the various component units of the reactors. In turn, these subcontractors sublet component unit parts to others—mostly small manufacturers. All of these are working on a fixed price and many have lost much through their dealings with the Westinghouse system of operation. Many refuse to make further attempts to enter or remain in the atomic field because of existing conditions.

Here are some of the obstacles confronting subcontractors dealing with Westinghouse:

(1) The lack of finding someone who will assume responsibility.

(2) Indecision.

(3) The loss of many weeks' delivery time to obtain answers to manufacturing questions.

(4) The refusal of Westinghouse to consider design changes which would better and simplify the product.

(5) Unnecessary interference by Westinghouse fieldmen in the course of manufacturing.

(6) Multitude of design changes and the many weeks wasted in obtaining release to proceed.

(7) Unrealistc manufacturing processes specified by Westinghouse.

(8) Delivery pressure caused by delay attributable to Westinghouse.

(9) Too much redtape.

Inasmuch as Westinghouse places the blame on the Atomic Energy Commission for most of these difficulties, it would be reasonable to assume that the Commission is out of touch with realism and has failed to provide the necessary leadership.

The time is long overdue for drastic changes in our atomic program, and I suggest the following changes to be of the utmost urgency:

(1) Decentralize the activities of the Westinghouse Atomic Division whereby the Atomic Energy Commission uses the Westinghouse facilties for research and prototype only.

(2) Award the prototype reactor design as a separate contract, to provide ideas for the technical and scientific manufacturing refinement, and allow such prime contractors to sublet such redesign, divided into practical units, to subcontractors whose facilities and organization are adaptable to each particular phase of mechanism.

(3) Place the manufacturing of each package as direct contract to private indsutry and the assembly and final testing as a contract by itself.

The above procedure will eliminate the present system of continuous design change during the actual construction, which thus far has been extremely costly, both in time and money. It will also speed the delivery and utilization of tremendous knowledge and gradually pave the way to greater things through individual ingenuity.

It is unfortunate that the spotlight on space travel has taken so much attention away from our atomic developments. Yet it is through the atom we will eventually conquer the mystery of gravity. If some other world power, such as Russia, gets ahead of us in this direction the free world is doomed.

I. T. WEDIN.

CADILLAC, MICH.

FURTHER DETAILS CONCERNING OUR DELAYED PROGRESS IN THE FIELD OF ATOMIC ENERGY, SUBMITTED BY I. T. WEDIN

With reference to previous résumé giving a general description of the reasons for our delay and difficulties in the field of atomic energy, this is to exemplify certain conditions in detail.

We are well aware of the infancy of atomic developments and the difficulties which had to be overcome to reach practical applications. Much of the credit goes to Admiral Rickover who at this early stage channeled the development of the reactors through the Westinghouse Corp. and by means of the Atomic Energy Commission. This practice as outlined in the early years served its purpose but it can no longer continue in the same pattern. Today the Westinghouse Corp., and especially the Bettis plant, has taken on a self-styled monopoly, both in the field of development and engineering as well as processing. They have reserved the complete right to give final jurisdiction to everything in the reactor field and have built up a small nucleus of men who in reality exercise more power than the Atomic Energy Commission itself.

In my previous résumé I am referring to the dividing line between scientific research, development engineering, manufacturing engineering, etc. All of these are one in the Westinghouse Corp. operation and all of the subcontractors are controlled by the opinions of this group.

In my objectives previously stated and the obstacles which are comfronting subcontractors dealing with Westinghouse Corp., the following will define the various points of criticism:

1. The lack of finding someone who will assume responsibility

Our company has at the present time a request for interpretation as to hardening procedure dating back more than 6 months. We have spent time and money through telephone calls, letters, and even trips to the Bettis plant to obtain an answer without any result whatsoever. One department head after another has passed on the responsibility to someone else and no one is in a position to submit a simple answer to a simple question.

2. Indecisions

The lack of finding someone who can make bona fide decisions is directly related to the lack of responsibility. We have found that simple and elementary questions in the process of manufacturing, which would ordinarily require only a formal verification, requires weeks of waiting time. From my dealings with major package subcontractors, this type of indecision is one of the greatest handicaps in trying to meet delivery and producing the product. We are ourselves indirectly affected by this type of indecision through our subcontracting dealings with Bendix Corp. and the Thompson Products Co. and others. In the case of Thompson Products Co. we have as an example in our plant parts completed 6 months ago which cannot be shipped or released because of the indecision on the part of the Westinghouse Corp.

It is nothing unsual to find a definite mistake in drawing specifications which will require 3 to 4 weeks for an official correction of such mistakes which in private industry would only require a limited number of hours.

3. The loss of many weeks of delivery time to obtain an answer to manufacturing questions

The delivery time in most instances is very short and hard to comply with in the regular course of manufacturing. Although the particular unit being manufactured is supposed to be released as to final workable design, continuous interruptions of many weeks are very prevalent through interpretation of design and drawing specifications. This can only illustrate my previous statement that the development stage and the prototype models have not received the proper attention through practical engineering before it is being released for manufacturing.

4. The refusal of Westinghouse to consider design changes which would better and simplify the product

Inasmuch as no monopoly exists on knowledge and ingenuity, suggestions are made from time to time to the Westinghouse Corp. as to practical solutions involving design changes and alterations of specifications. It is an established axiom that the Westinghouse Corp. will not consider these suggestions. This will hold true even in the case where the Westinghouse design is on the borderline of an impossibility from a practical standpoint. It has been a long-standing discussion by people involved in the making of component parts for reactors that the tolerance and limit specifications are carried out to a ridiculous degree.

5. The unnecessary interference by Westinghouse fieldmen in the course of manufacturing

From the small supplier to the larger subcontractors the picture is the same when it comes to occasional as well as stationary followups by Westinghouse fieldmen. Some of them are qualified, some of them to the contrary. The interference caused by these men is a direct outgrowth of the internal operation at Westinghouse and with logic thrown out the window. This situation should not be interpreted as a process followup and to determine the status of the progress made in each instance. It is in reality a case where the subcontractor is losing control of his own operation.

6. The multitude of design changes and the many weeks existing in obtaining release to proceed

Contrary to the assumption that the drawings of the particular unit to be manufactured are in their final stage, continuous design changes involve from time to time holdup of the entire manufacturing. Many weeks are lost before proper changes and decisions are made during which time no one knows what is going to happen next. The delivery time is also in this case seriously affected and obstacles of this type were not considered in the delivery promise given by the subcontractor.

7. Unrealistic manufacturing processes specified by Westinghouse

In this case the machining procedures and handling as outlined by Westinghouse cannot be followed to the letter by the individual subcontractor. Each plant because of its equipment, personnel, and engineering may be entirely different in procedures from the opinions stated by Westinghouse. The insistence to follow to the letter the Westinghouse manufacturing procedures has caused no end of trouble. It has magnified itself to the point where a subcontractor to the subcontractor is requested to fill out forms with lengthy descriptions covering every move in the manufacturing. It all adds up to a constant feeling of fear and uncertainty because of these unreasonable requirements.

8. Delivery pressure causesd by delays directly attributed to Westinghouse

The Westinghouse Corp. and through the demands from other sources are establishing delivery requirements without due consideration to many of the reasons previously stated. In order to conform to the promises given, the Westinghouse Corp. have time and time again exercised undue pressure on the suppliers without considering that they themselves are responsible for delays. Pressure of this type can cause great havoc and accomplish nothing. It illustrates again the end result of poor planning from various reasons already mentioned.

9. Too much redtape

A gentleman from W. F. Barnes Co. recently remarked that the reactor barrel itself would not be large enough to contain the paperwork which was required in the construction of the barrel.

At this moment we are about to ship to Babcock & Wilcox Co., 22 small items requiring over 1,300 inspection reports. This is not the end of it. Here is the sequence of redtape.

1. We produce these items and fill out 1,300 reports.
2. The regional Navy inspector has to recheck and confirm these reports.
3. An inspector from Babcock & Wilcox Co. comes to our plant and duplicates ours as well as the Navy inspection.
4. When the parts arrive at Babcock & Wilcox Co., they are subject to further inspection.

Roughly, the time required for this endless chain of duplications and redtape represents 25 percent of the time required to manufacture the parts.

In addition to the above it is required to submit reports in four copies of machining procedure, separate reports on heat treating, chrome plating, etc.

This is the ultimate example of the efficiency prescribed by the Atomic Energy Commission. Multiply the above procedure to every part which goes into the reactor, plus the subsequent reports covering subassemblies, tests, final assembly, and so on, and it will substantiate my claim that the reactor cost could be cut by 30 to 40 percent.

The above example is only one of the multitude of redtape. Deviation reports, authorization of this and that, progress reports, etc., are a continuous merry-go-round.

Aside from what already has been stated, the committee will find it quite interesting to bring about the reasons for many of the contractors not being able to fulfill their contract. Especially the methods used in pulling the jobs out of such plants for completion elsewhere, should serve as a warning in the future.

Because of the potential future in the field of atomic energy both large and small plants are interested in the participation. Unfortunately, most of the plants are submitting bids, not showing the hidden hazards created through the policies of AEC and Westinghouse. Bids are awarded on price and in numerous cases such awards are given with the full knowledge that the price is ridiculously low. In other words the chances of the bidder not to be able to fulfill his contract is a foregone conclusion. Private industry would never resort to these unwise tactics.

Then of course we have situations where companies are deliberately bidding low to "get in". Such was the case with Bell Aircraft, who lost millions on the deal and caused much detriment to the program.

It appears that a realistic appraisal is lacking which is costing our Government both money and time.

The condensed elaboration on each of the above points is only a fragment of what can be disclosed in each instant. The limited time I have available to bring this to the committee's attention, prevents me from submitting a broader view.

The question may arise among the members of the committee, why some of the larger contractors and subcontractors have not taken sufficient action to correct the abuse which hampers our atomic energy program.

The answer is very simple. They are very reluctant to step on anyone's toes within the framework of AEC or the Westinghouse combine because of fear of being eliminated as suppliers.

I sincerely suggest that one or more from the Joint Committee on Atomic Energy join me on a tour to various plants engaged in atomic work for a first-hand account of the true situation. The revelations obtained from such a trip would certainly require some serious considerations on part of the committee.

Respectfully submitted.

I. T. WEDIN.

(Following is correspondence between the Joint Committee on Atomic Energy and the Atomic Energy Commission, regarding the statements submitted by Mr. I. T. Wedin:)

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C., April 22, 1959.

Mr. A. R. LUEDECKE,
General Manager, Atomic Energy Commission,
Washington, D.C.

DEAR MR. LUEDECKE: Attached is a copy of a statement submitted by I. T. Wedin for the record of the "202" hearings.

Since the attached statement contains allegations concerning the Commission and its contractor, Westinghouse Electric Corp., the Commission may wish to submit comments for inclusion in the record along with the statement.

We would appreciate receiving any comments you may wish to submit as soon as possible since we are in the final steps of completing the record of the "202" hearings.

Sincerely yours,

JAMES T. RAMEY, *Executive Director.*

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., May 21, 1959.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy, Congress of the United States.

DEAR MR. RAMEY: Your letter of April 22, 1959, forwarded a statement made by Mr. Ivor T. Wedin, president of Wedin Corp., before the Joint Committee on Atomic Energy during the section 202 hearings. Since the statement of Mr. Wedin contains allegations concerning the Commission and one of its contractors, the Westinghouse Electric Corp., you suggested that the Commission may wish to submit comments for inclusion in the record along with the statement of Mr. Wedin.

The Committee is aware that exceptional precautions are necessary in the design and manufacture of naval nuclear propulsion plants in order to provide adequate safety to the public from possible effects of a radioatcive incident; also to provide the greatest reliability of operation of these plants for such severe requirements as submarine operations under the Arctic ice cap. To attain these objectives it has been necessary to maintain close control of design, to set the highest possible manufacturing standards and to establish rigid inspection procedures. This close control has on many occasions revealed flaws in design and manufacture which would have led to serious consequences had they remained uncorrected.

An example of the type of problem which confronts us is a case with which the Wedin Corp. is familiar. The Bettis Laboratory contracted with Borg-Warner Corp. for control rod drive mechanisms for the pressurized water reactor at Shippingport. These mechanisms move the control rods in the reactor which in turn regulate the nuclear reaction; thus the mechanisms are inherently associated with the safety of the nuclear plant. Borg-Warner subcontracted with Wedin for drive shafts for the mechanisms. During finish grinding of these shafts, one of them cracked. For normal industrial applications the probable course of action would be to scrap this one shaft and use all the others. For nuclear applications, however, since these drive shafts are used for controlling the reactor and because of the grave consequences that could result from a reactor incident, we had to find the reason why the drive shaft cracked. As a result, an intensive metallurgical investigation was undertaken. This investigation lasted about 2 months during which time the decision whether or not to use the other drive shafts was held in abeyance. A test was developed to

demonstrate the adequacy of these drive shafts, and before final acceptance all the drive shafts were given this test. The results showed that two other finished drive shafts had inherent weaknesses in them which could result in failure under reactor operating conditions. These two shafts also were rejected.

As a consequence of the above-described investigations, a delay of about 2 months took place before the remaining drive shafts were accepted. The delay was necessary, however, in the interest of minimizing the risk of failure of the drive shafts in service.

The situation in the case of the drive shafts described above is also typical of numerous other cases involving naval nuclear propulsion subcontractors. Investigations similar to this one have delayed completion of components but have uncovered defects in design, material, or workmanship unacceptable in reactor plants.

Mr. Wedin apparently is of the opinion that the Westinghouse Electric Corp. is the only AEC prime contractor engaged in the design and development of naval nuclear propulsion plants. As you know, the development of these plants is also being performed at the Government-owned Knolls Atomic Power Laboratory, operated for the Commission by the General Electric Co. Although the initial development work is done by these laboratories, the equipment for the nuclear plants is obtained on a competitive basis from private industry. For example, all Navy shipboard reactor cores, except the first core of a given type, are procured by competitive prime contracts. For most manufactured items, such as reactor plant components, the laboratories write the equipment specifications and the manufacturer designs, manufactures, and tests it.

This work requires the talents and initiative of many hundreds of subcontractors. The role of these subcontractors has not been easy. Components which at first glance appear simple are often found to be intricate. As Mr. Wedin points out in his letter, there may have been cases where companies have "bought in" to participate in the reactor program and have accepted initial loss for secondary benefits. We do not know how this can be avoided under the American competitive system.

Mr. Wedin suggests cessation of Government laboratory supervision of the manufacture of reactor cores and components after a prototype of a particular plant has been proven. This assumes that the successful operation of a prototype ends technical problems. This has definitely not been the case. The art of reactor manufacture is still in its early stages. Each new generation of reactor plant, even though the concept be proven, requires a high degree of technical followthrough to assure that every part, large or small, will meet the required specifications.

While recognizing that the nuclear power field is a highly developmental one, the Commission is continually seeking avenues for simplifying methods and procedures. Many suggestions by our contractors and subcontractors are constantly providing assistance in this task. However, we have proceeded cautiously in relaxing specifications and the degree of inspection for reactor plant components in order not to jeopardize the paramount requirement of safety to the public and to the ship and crew.

Sincerely yours,

A. R. LUEDECKE, *General Manager.*

SEEKONK, MASS., *February 27, 1959.*

Senator CLINTON P. ANDERSON,
Joint Committee on Atomic Energy,
Congress of the United States,
Washington, D.C.

DEAR SENATOR ANDERSON: I am glad to accept your invitation to present a statement in connection with the section 202 hearings for 1959. The comments which follow represent my personal judgments based on my observation of the development of the power reactor program during the past 10 years. The following comments relate to three of the topics in the list accompanying your letter of January 27.

1. The Government's power reactor policies and programs both domestic and foreign

Much progress has been made in recent months in defining objectives and schedules for a U.S. program to develop civilian nuclear power. A major con-

tribution was the program issued by the Joint Committee in August for review and criticism by the AEC and by the public. A second and equally significant contribution was the Commission's ad hoc committee report in January of this year.

There are great similarities between these statements in terms of philosophy and recognition of the substantial and continuing role of the Government in guiding the program and furnishing financial support. The general scope of the program of reactor development advocated in these reports seems close enough to be reconcilable to the degree that identity of view is desirable.

One difference may still reside in the concept of the size of plant needed to demonstrate effectively the technical and economic features of a nuclear powerplant. There seems to be agreement that the purpose of most, if not all, of the "uneconomic" reactors to be built in the United States in the next 10 years is to advance technology and to furnish a basis for design and construction of large plants and prediction of their characteristics. The ad hoc committee shows very clearly the cost of large versus prototype plants by computing the additional cost per hour of operation for a "large" plant and for a "prototype" plant.

For example, on page 29 of their report there is a comparison between a 200 EMW plant and a 50 EMW plant. Using the more probable figures of $1,200/hour and $400/hour additional cost per hour over a conventional plant and 7,000-hour year the additional cost of the 200 EMW plant over the 50 EMW plant is $5,600,000 per year.

If the additional value of operating data from the large plant in this case is equal to $5,600,000 times the years of useful life of the plant, then a large plant should be built. But if the data from the smaller plant can be reliably extrapolated to a large plant, a very large saving can be made by buidling and operating the 50 EMW plant.

I expect that the objectives and schedules and general content of program which will emerge from the section 202 hearings will represent a large measure of agreement among the Joint Committee, the AEC and industry. Such a measure of agreement will be of great help in promoting progress in this field which has for too long been hindered by rather deep differences.

4. The AEC's policy on the declassification and dissemination of information to industry and other users

Recent announcements indicate that a review is now being made with the objective of declassifying various kinds of information previously held classified. Special consideration should be given to declassification of such information as would make it possible for the AEC or some organization it might select to make and issue the following kind of study:

One of the objectives in the civilian nuclear power program should be the eventual withdrawal of the AEC from the determination of uranium concentrate prices, the processing of feed materials, the separation of U^{235}, the processing of spent nuclear fuel to recover fissionable material, and the disposal of radioactive wastes. The achievement of this objective may take a number of years. During this interim the term "competitive nuclear power costs"—meaning competitive with fossil fuels—has meaning only if we estimate as closely as we can the costs in the fuel cycle if all steps were done privately and compare such costs with those which prevail under the present system. The net difference should then be factored into estimates of "competitive nuclear power costs." If it shows that there is a subsidy, we should know how much it is and where in the fuel cycle it enters.

It is probable that a study of this matter would show that some parts of the fuel cycle are more expensive under the present system and others cost less than if financed and operated on a conventional commercial basis. It is also to be expected that changes in technology and economics will result in different costs 2 to 3 years from now. Hence, any study would require revision periodically in order to be valid.

Two reasons seem paramount in support of the value of such a study and its periodic updating.

(*a*) Reasons of foreign policy now justify acceleration of the development of nuclear power technology beyond the rate which normal commercial economic incentives would produce. Yet long term there is no reason why the Government should subsidize the nuclear power industry. There are plenty of things which will have to be supported by the Federal Treasury. Surely we don't want to add heedlessly to this load.

(*b*) Unless we make and keep an up-to-date estimate of the amount by which costs of the fuel cycle are above or below what they would be if privately owned and operated on a commercial basis, the term "competitive nuclear fuel costs" has little meaning. Such cost figures are open to attack either on the ground that hidden subsidies exist because of the present system or that excessive costs arise because of it.

The confusion and charges of misrepresentation arising from the present situation hinder the program and leave both the buyer of a nuclear powerplant and the equipment manufacturer in an uncertain position.

Up to this time it is understood that the AEC has not felt that it could declassify the information essential to make such a study meaningful. Yet the absence of such data casts justifiable doubt on the meaning of any existing estimates of "competitive nuclear power costs." It is to be hoped that during the current review of declassification special attention will be directed to this problem.

6. The AEC's contract policy in the reactor development field

One aspect of the AEC's present contract policy needs early change. That concerns the patenting of inventions. The effect of the patent clauses in AEC contracts is essentially to negate the value of patents. The objective has been to avoid the hindrance to anyone in the field by having to obtain rights from patentees whose inventions one may wish to use, or if rights could not be obtained, to abstain from use of the patented combination or to try to design around it. On the whole this may have accelerated development in the field thus far.

However, this policy has at least two adverse effects which are increasing in importance. The first concerns foreign patents. Generally, members of industry probably accept the need for acceleration of development in this civilian nuclear power field to serve the objectives of our foreign policy. They probably accept the need for the United States-Euratom program despite the consequent acceleration in the transfer of U.S. technology to the Euratom nations. But the thing they do find hard to accept is being barred from foreign markets by foreign patents on U.S. inventions which were never filed abroad.

It is well known that in many foreign countries the first person to file an application for a patent becomes the patentee regardless of whether he is the original inventor. Assume an invention is made by a U.S. firm working under an AEC contract. Either all patent rights, or all rights for governmental purposes (broadly construed) belong to the AEC. There is little incentive to the U.S. firm to file—or urge that the AEC file even a U.S. application. There is still less incentive to take on the burden of filing abroad. But the consequence of such neglect may well be that the invention will be patented abroad by a foreign patentee who may later bar the firm in which the invention was made from selling articles embodying the invention in such countries.

The second adverse effect of the present policy is that it works against the small company and favors the very large concerns. The reason for this is that small organizations traditionally have had to rely heavily on their ingenuity to compete effectively with organizations having vast resources. One expression of such ingenuity has been in patents which have been of great importance to the survival and growth of many small firms. But this means of protecting ingenuity through patents is just not available under the AEC patent clauses.

For at least these two reasons consideration should be given to changing the AEC patent clauses. Dr. Chauncey Starr recently suggested that a plan of compulsory licensing be adopted. Such a plan might be justified under the special circumstances existing in this field and deserves careful study. I do not wish to be understood as favoring compulsory licensing for general adoption in our patent system, but it might offer in this situation a sufficient incentive to patenting and yet avoid patent conflict and possible delay which might arise in the absence of compulsory licensing.

I appreciate the opportunity to participate in this important annual review of our atomic energy program. Much progress has been made in clarifying our national course.

Sincerely,

CARROLL L. WILSON.

WYOMING MINING ASSOCIATION,
Riverton, Wyo., February 23, 1959.

Hon. CLINTON P. ANDERSON,
Chairman, Joint Atomic Energy Committee,
U.S. Senate, Washington, D.C.

DEAR SENATOR ANDERSON: It will not be possible for a representative of the Wyoming Mining Association to attend the No. 202 hearings this week, hence we are submitting the following statement for the record.

The Wyoming Mining Association commends the Atomic Energy Commission for granting additional milling facilities to Wyoming producers. We urge that sufficient allocations be maintained so that uranium producers may operate their mining properties economically.

We do not recommend the extension of contracts for the purchase of uranium produced in foreign countries. We believe that present foreign contracts must be honored but the extension of such contracts would be unjust and unfair to our domestic producers of uranium.

We urge the continuation of the work of the Atomic Energy Commission in the field of scientific research and development. From such efforts we may anticipate a further expansion in the peacetime uses of uranium.

In conclusion, may we express our appreciation for the courtesies extended to our association by your committee.

Respectfully yours,

R. W. BEAMER,
Executive Secretary.

YANKEE ATOMIC ELECTRIC CO.,
Boston, Mass., February 11, 1959.

Hon. CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy,
Washington, D.C.

DEAR SENATOR ANDERSON: In response to your invitation, I should like to submit the following statement to be included in the record of the Joint Committee's annual hearings under section 202 of the Atomic Energy Act.

My comments on current developments in the atomic energy field can perhaps best be focused by a brief reporting on the status of Yankee's nuclear power project.

As you know, our project involves the construction and operation of a 134,000-kilowatt nuclear powerplant at Rowe, Mass., using a pressurized water reactor as a power source. The electrical output of the plant will be sold to our stockholder utility companies, who supply a major portion of the electrical requirements of the six-State New England area. Our project is one of the "first round" projects under the Commission's power demonstration reactor program, and the research and development program on which our plant design is based has been supported by a contract with the Commission dated June 4, 1956, which makes available a total of $5 million for research and development work and includes a waiver of use charges on special nuclear material for the first 5 years of operation.

During the past year we have made substantial progress on several fronts.

The research and development program, which is being carried out by Westinghouse Electric Corp. as our subcontractor, has been of major assistance in determining the design of the nuclear core and the components of the primary system. This program is now moving into the final stages of completion and evaluation, with primary emphasis on factors affecting probable core life and performance.

The necessary construction permit was issued by the Commission on November 4, 1957, and major construction work commenced at the site in the spring of 1958. Construction of the plant is being carried out by our joint contractors, Westinghouse Electric Corp. and Stone & Webster Engineering Corp., and is proceeding on schedule. Foundation and structural work was pushed ahead during the 1958 construction season and is now well advanced. Work at the site this winter is centered on the erection of the vapor container. The reactor vessel and other major components of equipment are being fabricated and installation of these components will commence during the coming con-

struction season. Progress to date confirms our original schedule, which calls for loading in the initial core and commending test operations during the latter half of 1960.

Cost experience to date has further confirmed our earlier estimates, and we have gone forward during the past year with plans to provide a suitable financing for our estimated $57 million of capital requirements. Funds necessary to carry forward the project to date have been supplied entirely by our stockholder utility companies, who have thus far invested a total of $13 million in common stock. We have now completed arrangements with a group of insurance companies for the purchase of an issue of our first mortgage bonds and with the First National Bank, of Boston, and a group of participating banks for unsecured bank loans of shorter maturities, so that our ultimate capital structure will be as follows:

5 percent first mortgage bonds, due Jan. 1, 1982	$20,000,000
4¾ percent bank loans	17,000,000
Common stock (all held by our 11 stockholder utility companies)	20,000,000
Total	57,000,000

Regulatory applications with respect to this program are now pending before the Massachusetts Department of Public Utilities and the Securities and Exchange Commission under the Public Utility Holding Company Act of 1935, and the program has been submitted to the Atomic Energy Commission as evidence of our financial qualifications in accordance with the provisions of our construction permit. As a measure of progress, we spent over $10 million prior to December 31, 1958, and expect to spend about $30 million in the year 1959 and most of the rest in 1960.

On the basis of these figures and our present estimates of plant performance and core life, we believe that, after steady operation has been achieved (perhaps for the life of the third core) our power costs should fall within the range of 12 mills to 14 mills per kilowatt-hour, with a fair possibility of lowering these costs if plant performance should exceed our present estimates or if fuel costs should be substantially reduced in the future. Measured against the steadily increasing costs of constructing conventional capacity and a similar upward trend of coal and oil prices, it seems probable that during the decade of the 1960's, power costs from our plant will approach the upper limits of power costs from new plants of conventional design in the New England area.

At the present time we are about at the half-way point of our program. Many problems that loomed large in earlier stages of our program have now been resolved. Major construction is well under way and progressing on schedule. Looking ahead, we are confident that the plant can be placed in satisfactory operation and that our practical experience in operating it will further assist in approaching the goal of economically competitive power costs.

We are very naturally interested in any developments in the field which may help us to achieve this goal. The fuel cycle development program now being formulated by the Commission is of particular interest in this connection, but developments on a broad front, both here and abroad and in all types of reactors, are no less important in view of the cross-fertilization of ideas that sparks new advances in nuclear technology. We anticipate that a part of this cost reduction will be due to manufacturing economies that come from volume production and competition and expect further benefits from technological advances and the adoption of new ideas. The actual figures will of course be importantly influenced by commission pricing policies on all phases of the fuel cycle costs.

Our experience to date has convinced us that our original decision to go forward with a first generation nuclear powerplant was well founded. We feel that the practical experience we will gain from operating it as a part of our integrated electric systems and improvements in performance that may be anticipated will pave the way for economically competitive plants within the next 6 or 8 years.

Yours very truly,

WILLIAM WEBSTER,
President.

(See also New England Electric System statement, p. 455.)

(Whereupon, at 5:25 p.m., Thursday, February 26, 1959, the hearing in the above-entitled matter was recessed, to be reconvened subject to the call of the Chair.)

APPENDIXES

APPENDIX 1

AEC REACTOR CONSTRUCTION COST AND SCHEDULE SUMMARY, FEBRUARY 1959

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D. C., January 27, 1959.

Mr. A. R. LUEDECKE,
General Manager, Atomic Energy Commission,
Washington, D.C.

DEAR MR. LUEDECKE: It is requested that the Atomic Energy Commission provide a summary of the status of the civilian power reactor program as of February 1, 1959. It is further requested that the Commission provide the figures on the original estimated cost and completion date and the actual cost and completion date or currently estimated cost and completion date for power reactors involved in (a) the 5-year experimental program; (b) the first, second and third round demonstration program; (c) the privately financed licensed program; and (d) the Government-sponsored Shippingport project. This data would in effect update similar information provided by the Commission in connection with the 1958 202 hearings, which information was printed on pages 569 through 577 in the record of the hearings.

In addition to the above information, the Joint Committee requests information on (1) fuel element development, including failure incidents, life performance tests and fabrication costs; (2) reactor operating experience, including operational costs and plant reliability data; and (3) any other significant developments in the civilian power program.

It is requested that this information be made available to the Joint Committee by February 9, 1959.

Thank you for your assistance in this matter.

Sincerely yours,

JAMES T. RAMEY,
Executive Director.

U.S. ATOMIC ENERGY COMMISSION,
Washington, D. C.

HON. CLINTON P. ANDERSON,
Chairman, Joint Committee on Atomic Energy,
Congress of the United States.

DEAR SENATOR ANDERSON: This will acknowledge your letter of January 27 requesting the submission of certain information prior to the 202 hearings.

The 25th Semiannual Report has been submitted to the committee. A reprint of the civilian application section of the report has also been submitted separately as background for the hearings. In preparing the summary of status of the civilian power reactor program as of February 1, as requested by you, we have not duplicated the infomation already submitted but rather have identified significant occurrences in January 1959 that were not included in the semiannual report.

We have updated the information printed on pages 569–577 of the 1958 hearings as requested by you. The order of submission follows the previous hearings, which is slightly different from that outlined in your letter.

We are submitting the additional information requested in your letter and by telephone in the following order: (a) Utilization of 1959 funds for fuel cycle development; (b) fuel element development information; (c) core fabrication

costs; (d) reactor operating experience, including plant reliability data and test operation cost for AEC civilian power reactor program; and (e) charts showing operating history of AEC civilian power program reactors.

We are not including a statement regarding other significant developments in the civilian power program since the chairman has presented an outline of our program to the committee and will cover this in more detail in oral testimony.

Sincerely yours,

A. R. LUEDECKE,
General Manager.

SUMMARY OF STATUS OF POWER REACTOR PROGRAM SIGNIFICANT EVENTS SUPPLEMENTING THE JULY–DECEMBER 1958 SEMIANNUAL REPORT

(1) Copies of the Semiannual Report, which covers the period July through December 1958, have been distributed. Significant events that have taken place in January which are not recorded in that report are set forth below.

(2) The ad hoc committee on reactor programs and policies submitted its report to the Commission on January 5. In view of the wide interest in this subject, the Commission made a public release of the report. Copies previously had been transmitted to the Joint Committee on Atomic Energy.

(3) It was announced on January 15 that Westinghouse Electric Corp. will build a pressurized water reactor for the General Public Utilities Corporation at Saxton in south central Pennsylvania. The plant, which will be wholly privately financed, will have a nominal power rating of 5,000 ekw. It will be connected to an existing turbine generator at the Saxton station of Pennsylvania Electric Co. of Johnston, Pa., a subsidiary of GPU. The reactor will be used to conduct a research and development program with primary emphasis on achieving cost reductions and increased efficiency in the use of nuclear fuel. Westinghouse has retained Gilbert Associates, Inc. of Reading, Pa., as a subcontractor for construction of the facility, which is scheduled to begin in May 1959.

(4) Regarding the 11,400 net ekw organic cooled and moderated reactor proposed by the city of Piqua, Ohio, the Advisory Committee on Reactor Safeguards has advised that an alternate site selection appears satisfactory provided a more substantial and dependable containment system is added to the present reactor design. The Commission is now having design work started on the additional containment for this reactor.

(5) The Commission announced on January 20 that it had received 11 proposals from industry and research and educational institutions for performance of test irradiation services. The proposals were in response to a Commission invitation issued last October. The irradiation services are to be performed in reactors specifically designed for testing purposes so that reactor materials and components can be subjected to an environment comparable to conditions in reactors for which the materials and components are intended. A portion of these services are to be used for the development of low cost fuel elements. The 11 proposals are now being evaluated by the Commission.

(6) In the aircraft reactors program, the development of SNAP–III—(systems for nuclear auxiliary power) was reported by the Commission on January 16. It is a 5-pound device capable of converting into 5 watts of electricity the radiation emitted by one-third of a gram of radioactive material. The objective of the SNAP program is the development of sources of auxiliary electric power for space missiles system. SNAP–III is a "proof of principle" device, developed in a practical size and with a practical power rating. It derives its energy from radioactive polonium 210. With a fresh quantity of radioactivity—3,000 curies—SNAP–III will generate electricity at the rated capacity of 5 watts at an efficiency of 8 to 10 percent. It is estimated that in the course of 280 days—two half-lives of the polonium source—SNAP–III could produce a quantity of electricity equal to the output of 1,450 pounds of the best conventional batteries available. This concept of SNAP–III was developed in 4 months for the AEC by the Martin Co. of Baltimore, in conjunction with the Minnesota Mining & Manufacturing Co. of St. Paul.

INFORMATION UPDATING COST AND SCHEDULE ESTIMATES ON CIVILIAN REACTORS

1. The costs shown include cost of plant construction and the costs associated with the fabrication or preparation of fuel elements associated with the initial core or loading (when this data is available). The cost of the related research and development program and operating costs are not included.

2. The original and February 1958 estimated cost and schedule for low-power operation are as given in the calendar year 1958 section 202 hearings and were identified as "original estimated cost" and "actual cost" or "current estimated cost." The current estimates shown below represent the most recent data available.

Five-year program

3. Pressurized water reactor (PWR), Shippingport, Pa. Original estimate of initial low-power operations, July 1957. Actual initial low-power operation, December 1957:

	Thousands
Original estimated cost:	
Reactor plant	$37,750
Turbine generator	10,000
Total	47,750
February 1958 estimated cost:	
Reactor plant	55,000
Turbine generator	17,500
Total	[1] 72,500
Estimated cost:	
Reactor plant	55,000
Turbine generator	18,577
Total	[1] 73,577

[1] Includes a $5 million investment by Duquesne Power & Light Co. in the project and a $500,000 contribution by Westinghouse Electric Co. Includes cost of the initial core, buildings, and supporting facilities. The February 1958 estimate includes cost of initial core ($12,400,000) and supporting facility.

4. Boiling water reactor (BWR), Argonne National Laboratory: Original estimate of initial low-power operation, December 1956. Actual initial low-power operation, December 1956:

	Thousands
Original fabrication:	
Reactor fabrication	$2,600
Fuel fabrication	900
Building and supporting facilities	1,000
Total	4,500
Actual cost:	
Reactor fabrication	3,636
Fuel fabrication	1,263
Building and supporting facilities	992
Total	5,891

5. Homogeneous reactors (HRE No. 2), Oak Ridge National Laboratory: Original estimate of initial low-power operations, June 1956; actual initial low-power operations, December 1957:

	Thousands
Original estimated cost:	
Reactor fabrication	$1,800
Fuel preparation	(1)
Building and supporting facilities	630
Total	2,430
Actual cost:	
Reactor fabrication	[2] 3,008
Fuel preparation	(1)
Building and supporting facilities	[3] 631
Total	3,639

[1] Negligible.
[2] Includes chemical fuel reprocessing facilities.
[3] Includes cost of building originally constructed to accommodate HRE No. 1, as well as cost of alternations necessary for HRE No. 2.

6. Sodium graphite reactor (SRE), Santa Susana, Calif.: Original estimate of initial low-power operations, June 1956; actual initial low-power operations, April 1957:

	Thousands
Original estimated cost:	
Reactor fabrication	$3,500
Fuel fabrication	200
Building and supporting facilities	(1)
Total	3,720
Actual cost:	
Reactor fabrication	7,281
Fuel fabrication	327
Building and supporting facilities	(1)
Total	[2] 7,608

[1] Construction of buildings and supporting facilities financed by NAA.
[2] Does not include costs ($1,400,000) power-generating equipment installed by Southern California Edison Co.

7. Experimental breeder reactor No. II (EBR–II), Argonne National Laboratory: Original estimate of initial low-power operations, March 1958; February 1958 estimate of low-power operation, July 1960; current estimate of initial low-power operation, May 1960:

	Thousands
Original estimated cost:	
Reactor fabrication	$12,000
Fuel fabrication	1,400
Processing plant	2,050
Total	15,450
February 1958 estimated cost	29,100
Current estimated cost:	
Reactor and power cycle	18,048
Fuel fabrication	(1)
Processing plant	7,920
Site 16, NRTS	3,132
Total	29,100

[1] Preliminary estimate for fuel is $1,893,000. (This cost is not to be included in the capital cost of the plant.)

8. Organic moderator reactor experiment (OMRE), national reactor test station; initial low-power operation, September 1957.

	Thousands
February 1958 estimated cost:	
Reactor fabrication	$2,030
Fuel fabrication	242
Building and supporting facilities	342
Total	2,614
Actual cost:	
Reactor fabrication	2,030
Fuel fabrication	242
Building and supporting facilities	342
Total	2,614

POWER DEMONSTRATION REACTOR PROGRAM, FIRST ROUND

9. Consumers Public Power District (SGR), Hallam, Nebr.: Original estimate of initial low-power operations, 1959; February 1958 estimate of initial low-power operations, 1962: [1]

Current estimate of initial low-power operations, November 1961:

	Thousands
Original estimated cost:	
Reactor	$13,129
Fuel fabrication	631
Land, buildings, and supporting facilities	2,649
Electrical generating facilities	8,701
Total	25,110
February 1958 estimated cost:	
Reactor	29,233
Fuel fabrication	(1)
Land, buildings, and supporting facilities	[2] 8,250
Electrical generating facilities	[2] 12,692
Total	50,175
Current estimated cost:	
Reactor	29,233
Fuel fabrication	(1)
Land, buildings, and supporting facilities	8,689
Electrical generating facilities	12,276
Total	50,198

[1] No current estimate available as core design is undergoing change.
[2] In the information in the 1958 hearings these figures were inadvertently reversed.

10. Yankee Atomic Electric Co. (PWR), Rowe, Mass. Original estimate of initial low-power operations, 1958; February 1958 estimate of low-power operations, 1960:

Current estimate of initial low-power operations, July 1960:

	Thousands
Original estimated cost:	
Reactor	$16,765
Fuel fabrication	(1)
Land, buildings and supporting facilities	2,275
Electrical generating facilities	13,880
Total	32,920

[1] Fuel cost not available at time of original estimate.

[1] EDITOR'S NOTE.—Refer to Atomics International Letter dated Feb. 20, 1959, p. 70, containing additional cost information.

	Thousands
February 1958 estimated cost:	
Reactor	$38,413
Fuel fabrication	3,600
Land, buildings and supporting facilities	4,084
Electrical generating facilities	11,420
Total	57,517
Current estimated cost:	
Reactor	38,413
Fuel fabrication	3,600
Land, buildings and supporting facilities	4,084
Electrical generating facilities	11,420
Total	57,517

11. Power Reactor Development Co. (FBR), Monroe, Mich.; original estimate of initial low-power operations, 1960; February 1958 estimate of initial low-power operations, 1960:[2]

Current estimate of initial low-power operations, August 1960:

	Thousands
Original estimated cost:	
Nuclear facilities	$34,300
Fuel element fabrication	3,500
Nonnuclear facilities	10,700
Total	48,500
February 1958 estimated cost:	
Nuclear facilities	[1] 37,020
Fuel element fabrication	([2])
Nonnuclear facilities	14,061
Total	51,081
Current estimated cost:	
Nuclear facilities	[1] 37,020
Fuel element fabrication	([2])
Nonnuclear facilities	14,061
Total	51,081

[1] This does not include PRDC allowance of $1,175,000 for working capital, or any allowance for research and development expenses, plant operating costs, or waiver of fuel use charges.

[2] Included in nuclear facilities.

SECOND ROUND

12. Rural Cooperative Power Association (BWR), Elk River, Minn.: Original estimate of initial low-power operations, 1959; February 1958 estimate of initial low-power operation, 1960: Current estimate of initial low-power operations, January 1961:

	Thousands
Original estimated cost:	
Reactor	$3,760
Fuel fabrication	([1])
Land, buildings, and supporting facilities	700
Electrical generating facility	1,725
Total	6,185

[1] Included in cost of reactor.

[2] EDITOR'S NOTE.—More information indicating increased cost estimates are contained in PRDC statement, printed on p. 461.

February 1958, estimated cost:	*Thousands*
Reactor	$8,990
Fuel fabrication	(1)
Land, buildings, and supporting facilities	700
Electrical generating facilities	1,750
Total	11,440

Current estimated cost:	
Reactor	9,383
Fuel fabrication	(1)
Land, buildings, and supporting facilities	700
Electrical generating facility	1,818
Total	11,901

[1] Included in cost of reactor.

13. Chugach Electric Association (SDR), Anchorage, Alaska. Original estimate of initial low-power operations, 1961; February 1958 estimate of initial low-power operations, 1962: Current estimate of initial low-power operation, July 1962: [3]

Original estimated cost:	*Thousands*
Reactor	$5,500
Fuel fabrication	(1)
Land, buildings, supporting facilities and electrical generating facilities	1,850
Total	7,350

February 1958, estimated cost:	
Reactor	9,229
Fuel fabrication	(1)
Land, buildings, supporting facilities, and electrical generating facilities	1,850
Total	11,079

Current estimated cost:	
Reactor	9,229
Fuel fabrication	(1)
Land, buildings, supporting facilities, and electrical generating facilities	1,850
Total	[2] 11,079

[1] Not available.
[2] These estimates are now being reviewed by the contractor for possible revision.

14. City of Piqua (OMR), Piqua, Ohio. Original estimate of initial low-power operations, 1961; February 1958 estimate of low-power operations, 1961: Current estimate of initial low-power operations, July 1961:

Original estimated cost:	*Thousands*
Reactor	$4,010
Fuel fabrication	------
Land, buildings, and supporting facilities	580
Electrical generating facilities	1,031
Total	5,621

[3] EDITOR'S NOTE.—The Sodium-Deuterium Reactor (SDR) was subsequently dropped from consideration for Chugach. See AEC letter dated Mar. 13, 1959, p. 86.

February 1958 estimated cost:	*Thousands*
Reactor	$4,677
Fuel fabrication	(1)
Land, buildings, and supporting facilities	1,780
Electrical generating facilities	2,175
Total	8,632
Current estimated cost:	
Reactor	8,058
Fuel fabrication	1,750
Land, buildings, and supporting facilities	1,780
Electrical generating facilities	2,175
Total	13,763

[1] Fuel for 5 years' operation to be supplied under contract for $1,746,000.

THIRD ROUND

15. Northern States Power Co., Sioux Falls, S. Dak. February 1958 estimate of initial low-power operation, June 1962. Current estimate of initial low-power operation, August 1962:

February 1958 estimated cost:	*Thousands*
Reactor	[1] $12,190
Fuel fabrication	(2)
Land, buildings, and supporting facilities	3,560
Electrical generating facilities	5,850
Total	21,600
Current estimated cost:	
Reactor	[1] 12,190
Fuel fabrication	(2)
Land, buildings, and supporting facilities	3,560
Electrical generating facilities	5,850
Total	21,600

[1] Includes superheater.
[2] Not available.

16. East Central and Florida West Coast Nuclear Power Group. Current estimate of initial low-power operations, June 1963.

Current estimated cost:	*Thousands*
Reactor	$10,585
Fuel fabrication	(1)
Land, buildings, and supporting facilities	4,600
Electrical generating facilities	[2] 10,700
Total	[3] 25,885

[1] Not available.
[2] Includes auxiliary facilities such as steam generator, condenser, etc.
[3] This is an order of magnitude estimate.

17. Carolina-Virginia Nuclear Power Association, Parr Shoals, S.C. Current estimate of initial low-power operations, June 1962.

Current estimated cost:	*Thousands*
Reactor	$18,141
Fuel fabrication	1,000
Land, buildings, and supporting facilities	(1)
Electrical generating facilities	(1)
Total	(1)

[1] Not available.

PRIVATELY FINANCED PROGRAM

Consolidated Edison Co. of New York (PWR), Indian Point, N.Y.:
Original estimated completion date: 1960.
February 1957 estimated completion date: 1960.
February 1958 estimated completion date: 1960.
Current estimated completion date: 1960.
Original estimated cost: $55 million.
February 1957 estimated cost: $70 million.
February 1958 estimated cost: $90 million.
Current estimated cost: $90 million.[4] [5]
Commonwealth Edison Co. (BWR), Dresden, Ill.:
Original estimated completion date: 1960.
February 1957 estimated completion date: 1960.
February 1958 estimated completion date: 1959.
Current estimated completion date: 1959.
Original estimated contract price: $45 million.
February 1957 estimated contract price, $45 million.[6]
February 1958 estimated contract price: $45 million.[6]
Current estimated contract price: $45 million.[6]
General Electric Co. (BWR), Vallecitos, Calif.:
Original estimated completion date: 1957.
February 1957 estimated completion date: 1957.
Completion date: August 1957.
Original estimated construction cost: $3 million to $4 million.[7]
February 1957 estimated construction cost: $3 million to $4 million.[7]
February 1958 construction cost: $2,500,000.[7]
Pacific Gas & Electric Co. (BWR) (Humboldt Bay project):
Estimated completion date: 1962.
Estimated construction cost: $19,500,000.[8]

INFORMATION ON FUEL ELEMENT DEVELOPMENT AND REACTOR OPERATING EXPERIENCE

A. Utilization of 1959 funds for fuel cycle development

1. In the fiscal year 1959 budget submitted to the Congress (pp. RD–41) $15 million was included for a fuel cycle development program. The Congress appropriated for the reactor development program a total of $416,622,000 instead of the $420,592,000 requested, or a reduction of $3,970,000.

Requested by AEC		$15, 000, 000
Applied to separations and waste systems development related to fuel cycle	−$2, 000, 000	
Application of a portion of reduction in appropriation made by the Congress	−2, 500, 000	
		−4, 500, 000
Total		10, 500, 000

[4] Includes research and development.
[5] EDITOR'S NOTE.—In testimony on Feb. 25, 1959, Mr. Fairmen, senior vice president, Consolidated Edison Co., stated the present estimate is $100 million. [See p. 276.]
[6] Relationship between this contract price and actual cost of construction is not known.
[7] Reactor fabrication including first core. Excludes $572,000 spent by Pacific Gas & Electric Co. for conventional powerplant facilities.
[8] Includes conventional turbine-generating equipment.

2. The $10.5 million available in fiscal year 1959 is being utilized as follows:

(*a*) Work assigned (as of Jan. 31, 1959):	
Idaho Operations Office: Phillips Petroleum Co	$450,000
Subtotal, IOO	450,000
Chicago Operations Office:	
Atomics International	1,484,000
Ames Laboratory	420,000
Bureau of Mines	380,000
Battelle Memorial Institute	627,000
Denver Research	60,000
Subtotal, COO	2,971,000
New York Operations Office:	
Vitro Manufacturing Co	43,000
Stevens Institute of Technology	45,000
Nuclear Metals, Inc	393,000
Martin Co	189,000
Sylvania Corning	200,000
Rensselaer Polytechnic Institute	200,000
Nuclear Materials and Equipment	108,000
Materials Research Corp	30,000
Metal Hydrides	50,000
Nuclear Development Corp	62,000
Combustion Engineering	62,000
Subtotal, NYOO	1,382,000
Oak Ridge Operations Office:	
Georgia Technology Institute	75,000
Oak Ridge National Laboratory	1,247,000
Subtotal, OROO	1,322,000
San Francisco Operations Office:	
General Electric-Vallecitos	222,000
General Atomics	110,000
American Standard	130,000
Gladding, McBean & Co	51,000
Aerojet-General	18,000
Subtotal, SFOO	531,000
Washington: Bureau of Standards	30,000
Subtotal—Washington	30,000
Total work assigned	6,686,000
(*b*) Work unassigned[1]	3,814,000
Total	10,500,000

[1] On Oct. 15, 1958, the Commission issued a public invitation for proposals to develop advanced and improved reactor fuel cycles for power reactors. In response to this invitation 111 proposals from 39 companies were received. These proposals are currently under review and these funds are earmarked to cover initial obligation for these proposals. It is expected that an additional $2,500,000 will be added to the $3,814,000 from available funds.

B. Fuel element development

3. The achievement of economical nuclear power depends upon the attainment of high-power densities and high reactor coolant temperatures concurrent with long useful fuel element life. Fuel element fabrication costs must also be minimized. All of these factors can be attacked directly through research and development of fuel element materials and the development of new and improved fabrication methods.

4. Research and development effort directed toward providing improved fuel elements have been recently accelerated and emphasized, both by increased effort on specific reactor fuel element types and by increasing the base of fundamental materials research.

5. A major portion of the funds allocated to the fuel cycle development program are being utilized to increase the breadth and tempo of reactor fuel element development. It is confidently exepected that this increased support of fuel element development over the entire spectrum from basic research to production fabrication will hasten the achievement of economical nuclear power. The current status and relative emphasis being placed on various fuel element concepts within the power reactor program is outlined in the following table and text:

Power reactor fuel estimates

Project	Reactor type	Fuel type	Cladding	Core status
Yankee	Pressurized H_2O	UO_2	SS	Design complete.
Pathfinder	Boiling H_2O	UO_2	Al–Ni	R. & D.
Dresden	do	UO_2	Zr–2	Fabrication.
Kaiser-ACF	Gas cooled	UO_2	SS	R. & D.
PRTR [1]	Pressurized D_2O	UO_2 and Pu–Al.	Zr–2	R. & D.
CVNPA [2]	do	UO_2	Zr–2	R. & D.
PWR	do	UO_2	Zr–2	Operating.
OMRE	Organic moderated	UO_2	SS	Operating.
Florida	Gas cooled	UO_2	SS	R. & D.
Elk River	Boiling H_2O	ThO_2–UO_2	SS	Design.
Borax	do	ThO_2–UO_2	Al–Ni	Cooling and examination.
Indian Point	Pressurized H_2O	ThO_2–UO_2.	SS	Design.
EBWR	Boiling H_2O	U–Zr–Nb	Zr–2	Operating.
EBR–1	Fast breeder	U–Zr	Zr–2	Do.
HWCTR	Pressurized D_2O	U–Zr	Zr–2	Research and development.
PRDC	Fast breeder	U–Mo	Zr–2	Febrication.
Hallam	Sodium graphite	U–Mo	SS	Design.
Piqua	Organic moderated	U–Mo	Al	Do.
EBR–II	Fast breeder	Fissium	SS	Research and development.
SRE	Sodium graphite	U	SS	Operating.

[1] Natural U with Pu–Al alloy spike elements.
[2] Will probably be hollow pellets with high melting ceramic cores.

6. As listed in the table, the major current emphasis in fuel element development involves the use of UO_2 or UO_2–ThO_2, clad in aluminum alloy, Zircaloy-2, or stainless steel. The use of UO_2 instead of metallic uranium results primarily from the instability of metallic uranium under irradiation at temperatures in excess of 450° C. This instability is manifested by swelling of the fuel as gaseous fission products are released. Improved chemical compatability with water also is an important advantage of oxide over metal for water-cooled reactors. The benefits derived from the radiation stability of UO_2, and its compatibility with cladding materials, as compared to metallic U, must be balanced against the low thermal conductivity of the UO_2, the poisoning effect of the oxygen, and the fabrication problems involved.

7. The current status of UO_2 fuel element technology allows the fabrication of fuel elements that consist of metallic tubes filled with stacked UO_2 pellets which have been ground to uniform dimensions. Helium is used to provide a thermal bond between the pellet and the clad.

8. Advanced research is directed toward increasing the thermal conductivity of the UO_2 by addition of metallic fibers, or small percentages of other oxides. Fabrication costs are being reduced through the application of techniques such as compressing tubes containing UO_2 powder by swaging, coextrusion of the oxide core and clad, or hydrostatically pressing the cladding to the oxide core to achieve a satisfactory thermal bond thus reducing the current close dimensional requirements for UO_2 fuel pellets and the cladding tube.

9. An intensive research and development effort has been initiated which may lead to the use of uranium carbide as a substitute for UO_2. UC has excellent thermal conductivity and thermal stability and high uranium content per unit volume. Preliminary irradiation tests indicate favorable irradiation stability.

A major limitation is the high chemical reactivity of UC to H_2O which will act as a deterrent to the use of UC in water reactor systems, but UC is expected to have application in sodium and gas-cooled reactor systems.

10. The fabrication of metallic uranium alloy fuel elements with stainless steel or zircaloy-2 cladding is within the capability of current technology. Zircaloy-2 and U–10 percent Mo fuel elements are being fabricated for the PRDC reactor and Zircaloy-2 clad U–5 percent Zr–1.5 percent Nb elements are being utilized in the EBWR. The addition of Mo to U increases the strength of the alloy and improves the thermal and irradiation stability. The U–5 percent Zr–1.5 percent Nb alloy is resistant to water corrosion and has improved strength thermal and irradiation stability over metallic U. These alloys can be expected to perform satisfactorily at 650° C. in the case of U–Mo and 290° C. in the case of U–5 Zr–1.5 Nb but with a much lower allowable burnup than can be tolerated with UO_2 fuel elements before distortion becomes excessive.

11. The research and development effort on urnanium alloys that offers the greatest ultimate hope is a concerted effort now underway to determine the mechanism which produces swelling of U under irradiation and through an understanding of the swelling process to arrive at methods of increasing the irradiation stability of metallic uranium. This investigation coupled with the possible use of high strength cladding to restrain swelling, and the search for improved radiation resistant U alloys, could eventually lead to the increased use of metallic U fuel elements.

12. Final selection of an optimum fuel composition for the fast reactor, EBR–2, is imminent. This alloy will probably be metallic uranium with 5 to 10 percent Fissium (an equilibrium fission product alloy) with 1 percent to 5 percent Zr. These alloys have been found to be remarkably resistant to irridation damage and it is anticipated that 1 to 2 atomic percent burnup can be achieved without difficulty. The cross section of these materials for capture of thermal neutrons makes this alloy unattractive for thermal reactors.

13. Promising results are being obtained in the search for improved fuel element cladding materials. Aluminum-nickel alloys are being used in boiling water reactors. These alloys are cheaper than Zircaloy and have a lower cross section than stainless steel. Experimental aluminum alloys have been developed that are capable of withstanding aqueous corrosion at temperature much higher than is allowable from conventional aluminum alloys, if the coolant water used is acidic (pH 4.5).

14. Encouraging experimental results have been obtained from irradiation tests of uranium bearing graphite. Fueled spherical graphite samples have been irradiated at temperatures in excess of 1,100° C. without appreciable degradation of physical properties. Experimental measurement of the ability of these graphite spheres to retain fission gases are underway. Protective coatings have been developed that are resistant to oxidation and show promise for use as fission gas diffusion barriers to prevent fission gas escape. The graphite "pebble" fuel element concept, either with unclad graphite spheres with the fuel concentrated at the sphere center, or a homogeneous graphite-fuel mixture with a ceramic cladding, cooled by an inert gas shows promise of providing a very economical high temperature fuel cycle.

C. Core fabrication costs

[In thousands of dollars]

	Core No. 1 [1]	Core No. 2	Core No. 3	Core No. 4
PWR	12,400	13,000		
BORAX No. 4	78			
No. 5	715			
EBWR		1,400		
OMRE		78	170	170
SRE		155	585	
EBR–1			676	

[1] In most cases the cost of the 1st core was included in the construction costs.

D. Reactor operating experience (including operational costs (see table attached) and plant reliability data)

15. This report presents a summary of the operating history of the presently operating civilian power reactors built for the AEC. It includes PWR, Borax, EBWR, OMRE, SRE, EBRI, and HRE I and II.

16. It should be noted that the operating costs indicated for each reactor are not comparable with one another. The operating cost totals may include some research and development done on or with the reactor, fabrication of additional cores or additional fuel elements, maintenance, repair, and training of operators, as well as those items usually considered to be "normal" operating costs.

17. The difference among the various costs is attributable to differences in bookkeeping and budgeting practices of AEC contractors.

18. A table indicating core fabrication costs of the various reactors described in this report follows at the end of the section on operating history.

19. PWR—Shippingport: The Shippingport Atomic Power Station (PWR) reached full power (60,000 kilowatts net electrical) on December 23, 1957. The first 6 months of 1958 were devoted to conducting a wide variety of tests to insure that the plant and its systems and components performed in accordance with the design requirements. Between July 1, 1958, and November 3, 1958, two 1,000-hour continuous full-powered tests were conducted. Following each 1,000-hour run the plant was shut down to conduct other tests to determine the effects of the extended high-power operation on the reactor and other components. In addition to demonstrating the operability of the plant as a part of utility system under realistic conditions, the 1,000-hour tests provided valuable information in such areas as reactor core lifetime, primary coolant radiochemistry, and primary plant radioactivity levels. Extended periods of steady power operation, such as these 1,000-hour tests, are necessary to obtain reliable data on these characteristics because they change with time, and are affected by the plant power level, and thus never reach steady values unless plant power is held steady for a long period.

20. The major equipment difficulties experienced since the PWR went into operation involved primary coolant pumps and the turbine generator unit. In June 1958 the stator windings of one of the four primary coolant pumps were shorted due to failure of the sealing can which protects the stator windings from the primary coolant. No leakage of primary coolant to the atmosphere resulted. In December 1958 a second primary coolant pump experienced failure of both radial bearings. In both of these cases, plant operations continued on the other loops during pump replacement. This was possible because the plant can produce full power on three loops while the fourth is isolated for maintenance.

21. On November 22 a routine inspection of the moisture separator on the main turbine revealed a failure of the first stage separator. The separator is a part of the turbine generator unit and is used to remove moisture from the steam as it passes from the high pressure section to the low pressure section of the turbine. The failure was in no way connected with the nuclear plant and did not cause any damage to the nuclear plant. The plant was shut down for approximately 2 months while the necessary repairs were being effected.

22. During the first year of operation the total activity of radioactive wastes discharged from the plant was less than that permitted for a single month. A report on the design and operating experience of the waste disposal plant at Shippingport was submitted to Congress for the waste disposal hearings on January 28–30, 1959. There have been no overexposures of personnel to radiation.

23. During the first year of operation there were a total of 15 scrams (automatic shutdowns). A tabulation of these scrams is as follows:

	No. of scrams	Scrams/1,000 hours critical
Caused by personnel	10	2.17
Caused by equipment	5	1.08
Total	15	3.25

There were no scrams during the last 1,000 hours of operation.

24. The following is a tabulation of pertinent data on the PWR operation during the first year:

Equivalent full power hours	2,798
Hours critical	4,608
Electricity delivered, kilowatt-hours (net)	156,000,000

25. Borax: The first Borax reactor was an experiment to demonstrate the nuclear stability of a boiling-water-cooled reactor under atmospheric pressure. It also provided information relative to reactor power excursions . The first Borax experiment was initiated in 1952. Construction was completed in 1953.

26. The first operating results were made available on September 4, 1953. These results indicated no damage to fuel, no evidence of runaway power excursions and that peak power was limited by loss of reactivity in voids caused by boiling. Plans were initiated to perform tests in which the pile period would be shortened by increasing reactivity. About 50 of these excursions were run (4.9 milliseconds was fastest period) without serious damage to the reactor.

27. On July 21, 1954, the Borax I reactor was deliberately subjected to a short period excursion of approximately 2 milliseconds. Two additional fuel elements had to be added to the reactor. The excursion was initiated by removing all safety rods from the core, then rapidly removing the excursion rod. The reactor was destroyed and the facility damaged by the explosion. Records indicated that the excursion was no larger than predicted and that the explosion probably came from a chemical reaction of the uranium-aluminum alloy and water.

28. The construction of Borax II, a more permanent type of facility, was initiated on September 15, 1954, and went critical later that year. Early in 1955 construction was started for a turbine generator building and a new core. This facility was designated as Borax III. On July 17, 1955, electricity from Borax III was used to supply the needs of Arco, Idaho. This was the first occasion where the complete requirements of a community were supplied by a nuclear plant. The Borax III experiment was conducted with no major accidents.

29. A ThO_2-UO_2 fueled core was installed in the Borax facility and the succeeding experiment called Borax IV. The facility went critical on December 3, 1956. In February 1958 it became apparent that there had been a fuel element failure in the Borax IV reactor. An increase in activity in the turbine room (up to 70 Mr/hr) was the first indication of the failure. The reactor was shut down. A subsequent startup resulted in radiation levels of 400 Mr/hr in the turbine room and 8 R/Hr in the hot well. An analysis of the water indicated 30 Min half life believed to be cesium 138. The reactor was subsequently started and operated with the failed fuel elements to obtain data on the effects of such an occurrence.

30. The reactor was shut down and examinations made to detect the faulty elements. Of the 15 elements showing evidence of leaks, 2 were removed and sent to the laboratory for testing. The tests indicated mechanical stress failure at end closure of clad as source of failure. The reactor was shut down indefinitely in April 1958 pending modification to Borax V.

31. Experimental boiling water reactor (EBWR): The experimental boiling water reactor is a facility at ANL to demonstrate the technical feasibility of a boiling water cooled power reactor. Designed for a nominal heat rating of 20 MW the EBWR has operated at a power level of 61.7 MWT with no modification of the core. The principal operating difficulties with the EBWR were malfunction of the air ejector and failure of a turbine blade. These were nonnuclear in origin. The turbine was disassembled and repaired by routine maintenance with no limitation or difficulties due to radiation in spite of over a year of operation on steam produced directly in the reactor core.

32. A leaky condenser tube in the EBWR was repaired by reducing reactor power to 5 MWT, closing off half of the condenser water box, thus enabling maintenance personnel to enter the condenser and repair the tube with the reactor operating. No person received more than his normal tolerance dose rate during this period. The reactor was operating with a 10 mill hole in the cladding of an experimental oxide fuel sample at the time.

33. There have been no emergency scrams on EBWR due to nuclear malfunction.

34. The plant has operated with deliberately failed fuel elements in the core to provide data on activity carryover. Operation with these elements has not

placed any undue restriction on plant operation or the working environment around the reactor or the turbine.

35. The plant has demonstrated the ability to follow load changes and shows every indication of being a reliable reactor to operate, and no problems or restrictions in maintenance due to radiation or nuclear problems have occurred.

36. Vallecitos boiling water reactor has operated for over 1 year and has corroborated the operating experience of EBWR.

37. Organic moderated reactor experiment (OMRE) : The organic moderated reactor is attractive because of its relatively low initial cost. The chief areas of uncertainty in the organic reactor approach to nuclear power are the decomposition rate of the coolant and the possibility of film deposition ("fouling") on the heat transfer surfaces under ambient reactor conditions. Results of studies with diphenyl, ortho terphenyl, meta terphenyl, and mixtures of polyphenyls in electron-beam experiments, capsule and loop experiments in reactors, and thermal loop experiments have been very encouraging.

38. Thus, the real question determining the utility of or organics as reactor coolants and/or moderators is the question of the extent to which they are affected by radiation damage.

39. The organic moderated reactor experiment (OMRE) which went into operation at the Commission's National Reactor Testing Station in Idaho on September 17, 1957, has been designed specifically to test the practical feasibility of organic materials as reactor coolants and/or moderators.

40. Failure of a deflector skirt necessitating complete unloading and partial dismantling after criticality had been achieved. The difficulty was corrected and the reactor was back in service within 11 days.

41. The reactor and its coolant system were found to be quite stable under automatic control. With no automatic control, the reactor and its associated heat transfer system were found to be stable except for some very low frequency oscillations. The period of the oscillations was independent of the magnitude of the reactivity perturbation. The oscillations were divergent at 550° F. and convergent at 600° F. and the period was 25 minutes at 2.5 MW.

42. The decomposition of the terphenyl has been measured under three different operating conditions. Values of 86, 90 and 125 pounds of terphenyl decomposed per megawatt-day of heat were observed. The coolant temperatures covered were 600, 650–670 and 700° F. respectively with the fuel surface at 750° F. in each case. These values agree quite well with predictions based on previous experiments on thermal loops, capsule irradiations and in-pile loops.

43. The reactor was operated without purification of the organic until a 40 percent polymer concentration was reached. At this point the coolant inlet temperature was 600° F., the maximum fuel plate surface temperature was 750° F. and the nominal power 5.3 MW. The decomposition rate under these conditions was about 25 lb/MWH of energy. At about 39 percent HBR the first noticeable decrease in heat transfer coefficient was observed.

44. One of the attractive features of the organic type of reactor is the use of iron and mild steel rather than stainless steel for the entire coolant system. Another is the fact that the coolant outside the reactor core is essentially nonradioactive so that the entire primary coolant system is completely accessible for inspection and maintenance during operation. The reactor has operated quite satisfactorily at power loads up to 12 megawatts of heat and with coolant outlet temperatures up to 700° F. with fuel element surface temperatures as high as 750° F.

45. More recently, significant amounts of fission product activity were observed in the organic coolant indicating a fuel element failure. Two experimental Piqua elements which were being examined for heat transfer and burnup data were removed. Examination showed that particulate matter had been caught in the end of the interstice between plates where the coolant enters the channels.

46. Overheating of the element resulted in melting of the Al clad and exposure of several square centimeters of uranium alloy fuel.

47. The reactor is presently shut down. Cleaning of the coolant is in progress. A small amount of uranium from the damaged Piqua element and the particulate contaminant which caused the failure will be separated out. A new core loading will be installed early in 1959 and more experimental fuel elements, including some like those planned for the reactor for Piqua, Ohio, will be tested.

48. Sodium reactor experiment (SRE): The sodium reactor experiment is the primary tool being utilized in the development of the technology associated with the sodium-graphite type of reactor. This approach to nuclear power holds promise because of the high temperatures, and hence efficiencies, at which the heat transfer systems employing liquid metals can be operated without pressurization.

49. The reactor was originally designed as a flexible facility which could be used not only to gain operating experience with a sodium-graphite plant but also to determine the effects of ambient conditions on a variety of reactor materials. The reactor is designed to produce 20,000 kilowatts of heat and 6,500 kilowatts of electricity.

50. Initial experience with the operation and maintenance of the sodium reactor experiment has been encouraging. The reactor was loaded to criticality in April 1957. The amount of uranium required was in satisfactory agreement with calculations and gives added confidence to theoretical predictions on the neutron physics of the system. During the series of initial tests at low power, static and dynamic temperature coefficients were determined. The dynamic coefficient is strongly negative, as expected, and is the origin of the overall negative power coefficient of reactivity observed during later power tests.

51. Beginning in July 1957, the reactor and electric generating system were operated on several occasions at various power levels and a large amount of detailed test data was obtained and evaluated. Information on temperature distribution in the neighborhood of the main tank nozzles indicated the advisability of restricting the temperature differential across the reactor to 150° F. until means for improving the match between reactor power and coolant flow following scram could be installed. For this reason, subsequent power runs during the period July to December 1957 were made at one-third of full design power. An eddy-current brake was installed in March 1958 on the main sodium circuits after loop tests had demonstrated that satisfactory performance could be anticipated.

52. The sodium heat transfer system can be operated routinely and maintained under normal, and occasionally abnormal, circumstances. A few bellows seal valves have required replacement, which was accomplished with ease during a routine shutdown of the plant. The removal and replacement of the disposable cold trap has also been simple to carry out. On one occasion, a fuel element accidentally broken during insertion was removed during a single day with grappling tools devised for this purpose.

53. The temperature of the sodium entering the reactor ranged from 390° F. to 505° F. during the various runs and during the peak power production the temperature of the sodium leaving the core was 675° F. The corresponding steam conditions for the third run were 628° F. and 470 psig.

54. The ability of the combined SRE and Southern California Edison plants to produce electric power was demonstrated during the period from July through September 1958 by extended power runs. There were 151 MWd of reactor operations at full power during July, 432 MWd during August and 306 MWd in September. The electrical power generated during the same months was 982,000 kilowatt-hours, 2,785,650 kilowatt-hours, and 2,058,000 kilowatt-hours, respectively. The total power generation for the reactor to the end of October was 1,121 MWd; the total electrical power produced was 6,987,750 kilowatt-hours.

55. The reactor has been used extensively as a test facility. Mixed clusters of various experimental fuels are constantly being tested metallurgically and reactivitywise.

56. The reactor was shutdown at the end of September for extensive maintenance and modification. The steam generator from the SIR, no longer needed by that project, was connected to the SRE secondary sodium system. A tetraline leak in the freeze seal of the main secondary sodium pump was repaired. Fuel elements were reorificed, sodium leaks in the bellow seals were repaired, and the reactor was returned to low-power operation for physics tests early in November.

57. The extended outage resulted in a high sodium-oxide content of the coolant as evidenced by unusually high temperatures in several fuel channels. Cold trapping helped because the high oxide content and the reactor resumed full power operation in January 1959, subsequent to the completion of intermediate power pile oscillator tests.

58. Experimental breeder reactor No. 1 (EBR–1): Early work on fast reactors was initiated in 1945 at the Argonne National Laboratory and led to the construction of the Experimental Breeder Reactor No. 1 (EBR–1) at the National Reactor Testing Station.

59. EBR–1 was designed primarily to study the physics and breeding characteristics of fast reactors and, secondly, to study the technology of liquid metals as coolants. Construction of EBR–1 was approved in late 1947; the reactor went critical in August 1951. In December of that year, it produced the world's first electricity from atomic energy. Subsequently, it provided electricity for self-contained operation of plant and associated laboratory facilities for a period of years.

60. Operation of EBR–1 on its first core from 1951 to 1954 demonstrated that breeding was feasible. Additional experiments were carried on with the second core until November 1955, when the fuel rods melted as a result of an experiment concerned with measuring changes in reactivity as temperature of the fuel elements was increased rapidly. These experiments were undertaken to seek causes for power oscillations in the reactor. It was found that oscillations of power occurred when operating conditions were made severe; i.e., high power with reduced flow of coolant. Oscillations became more severe as power was increased or flow decreased. During the November 29 experiment, reactor power was made to rise with no flow of coolant—a calculated risk. The reactor was not shut down until powers exceeding those of normal operation were reached. The overshoot created temperatures high enough to melt fuel rods in the core.

61. In November of 1957, the EBR–1 went critical with its third core, Mark III and an extensive study of the reactor kinetics began. The first phase of the study was the conducting of oscillator tests with both series and parallel coolant flow. In this phase, the core is restrained so as to minimize the motion of the core subassemblies and fuel rods. To date, this experiment has shown the reactor to be stable at all power levels within its design limits and a prompt positive coefficient of reactivity has not been observed. The second phase of the investigation, scheduled to begin in February, will be conducted with the restraining devices in the core modified to permit motion of the fuel. These experiments will then define the effect of radial motion of the fuel upon the reactor kinetics.

62. Early in 1959, fabrication will begin on a plutonium alloy core which will be installed in the reactor late that year. The reactor will then produce power from plutonium fuel, and the nuclear parameters of the plutonium loading will be evaluated.

63. Homogeneuos reactor experiment No. 1 (HRE–1): The first aqueous homogeneous power reactor experiment (HRE–1) was designed to explore the nuclear characteristics of a reactor containing a circulating uranyl sulfate solution in light water (H_2O) surrounded by a heavy water (D_2O) reflector. The fuel solution circulated at nearly 500° F. under a pressure of 1,000 pounds per square inch. The power density was 30 kilowatts per liter. HRE–1 had a nominal thermal capacity of 1,000 kilowatts and utilized a small turbogenerator to produce 140 kilowatts electrical power during its operation. Criticality was first achieved on April 15, 1952. The first electricity was generated on February 24, 1953. Between this time and the spring of 1954, when the reactor was dismantled, liquid was circulated for about 4,500 hours during which time the reactor was critical for almost 2,000 hours. The reactor attained a maximum thermal power of 1,600 kilowatts.

64. Homogeneous reactor experiment No. 2 (HRE–2): Located on the same site as the dismantled HRE–1, the second aqueous homogeneous reactor experiment (HRE–2) has a designed thermal output of 5,000 kilowatts. The reactor is designed as a two region system with a heavy water based uranyl sulfate solution in the core and heavy water as a reflector in the blanket. The core and blanket are separated by a welded zircalloy core tank of light gage construction which is contained in a heavy steel outer pressure tank.

65. Construction of the reactor began in August 1954 and the reactor was essentially completed in May 1956. Nuclear operation of the reactor was delayed until December 1957 by stress-corrosion cracking caused by chloride-ion contamination in the stainless-steel leak-detection tubing and flanges. This necessitated the replacement of 132 flanges and 10,000 feet of tubing. During this replacement, a series of nonnuclear tests were carried out at design temperature, pressure and uranium concentration.

66. During January–March 1957, the reactor was operated for 1,382 hours, including 665 hours with water at full temperature and pressure, 520 hours at 1,700 pounds per square inch pressure and 536° F. with depleted uranium in the form of uranyl sulfate in solution in the primary system.

67. After these engineering tests were completed, the reactor was gradually brought up to full thermal power, 5,000 kilowatts, on April 4, 1958. This initial full-power run was terminated almost immediately because fuel from the core system was found to be leaking into the heavy-water blanket. The plant, which had produced about 326 megawatt-hours of nuclear heat and had operated in a stable manner at design conditions, was thereupon shut down for examination. The failure in the zircalloy core tank was not visible with available equipment, but its approximate size and location were determined indirectly.

68. The reactor was then prepared for operation as quasi-two-region reactor with fuel solution present in both the core and blanket regions, the fuel concentration in the blanket being kept low by a continuous purge. The reactor was successfully operated in this manner on a trial basis from June 4 until July 3, 1958, when the reactor was shut down routinely to prepare for extended operations. Operation was resumed on July 28 and continued to September 12. This operation was mechanically trouble free, but was characterized by occasional brief fluctuations in power level.

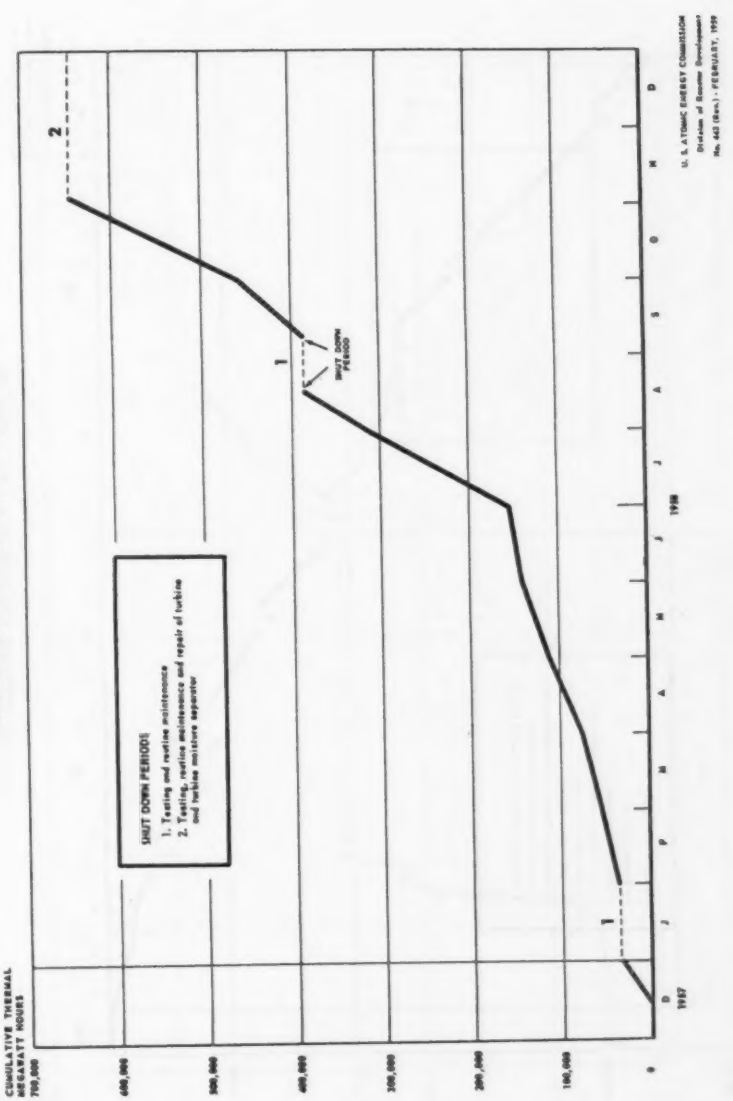
69. A complete inspection of the HRE–2 in September disclosed an oval hole measuring about 1½ by 1 inch in the core tank. Examination of the core region indicated a general thinning down of the core liner and extensive corrosion attack in the region of the diffuser screens which distribute the flow of fuel solution at the reactor inlet. Metallurgical examination of samples removed from the diffuser screens indicated that very high temperatures had been developed in the metal.

70. The evidence accumulated indicates that the observed power fluctuations, the high temperatures, and corrosive attack are caused by instability of the fuel solution which results in a concentration of fuel in certain localized areas. HRE–2 operation has been resumed and major attention is being given to finding and controlling the mechanism by which the instability occurs.

Test operator cost for AEC civilian power reactor program: estimated fiscal year 1959 as included in the fiscal year 1960 Presidential budget

Shippingport atomic power station (PWR)	$1, 820, 000
Experimental boiling water reactor (EBWR)	417, 000
Boiling reactor experiment No. 4 (BORAX–4)	320, 000
Homogeneous reactor experiment No. 2 (HRE–2)	1, 800, 000
Experimental breeder reactor No. 1 (EBR–1)	233, 000
Sodium reactor experiment (SRE)	1, 430, 000
Organic moderated reactor experiment (OMRE)	1, 223, 000

NOTE.—Test operations include cost for salaries and wages of the operating staff, utilities, supplies and materials, and repairs of the facilities. (Excludes all research and development and cost associated with fuel.)


OPERATING HISTORY OF AEC CIVILIAN POWER PROGRAM REACTORS
SHIPPINGPORT ATOMIC POWER STATION
CUMULATIVE THERMAL MEGAWATT HOURS
700,000
600,000
500,000
400,000
300,000
200,000
100,000
0
SHUT DOWN PERIODS
1. Testing and routine maintenance
2. Testing, routine maintenance and repair of turbine and turbine moisture separator
SHUT DOWN PERIOD
1
2
D
1957
J
F
M
A
M
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J
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O
N
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1958
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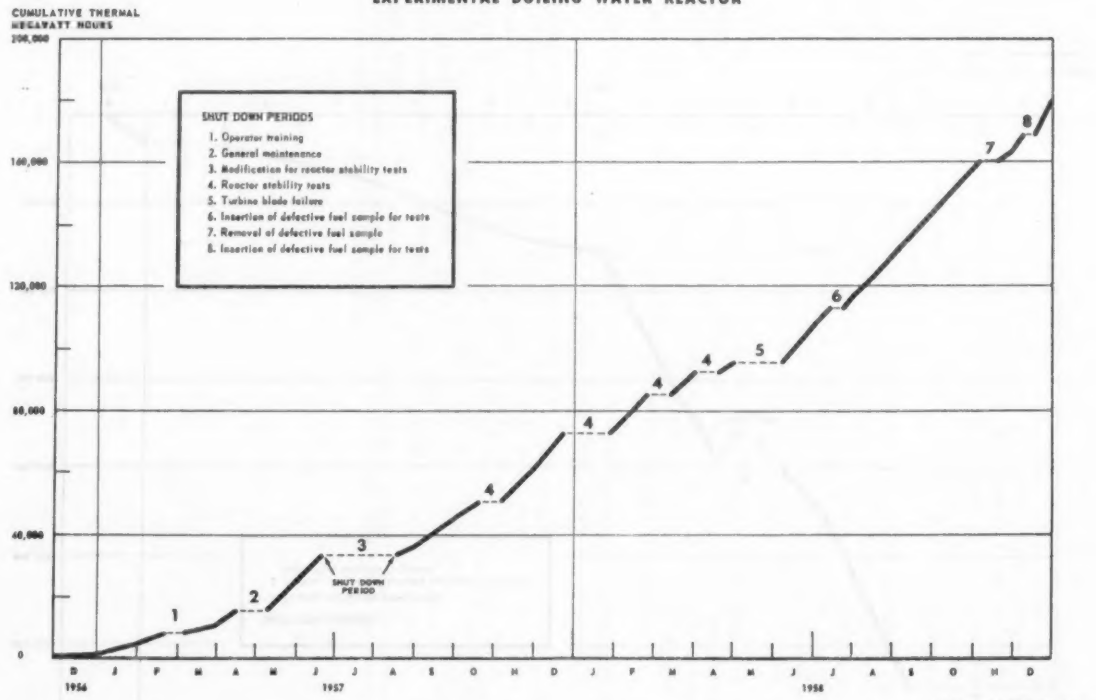
OPERATING HISTORY OF AEC CIVILIAN POWER PROGRAM REACTORS

EXPERIMENTAL BOILING WATER REACTOR



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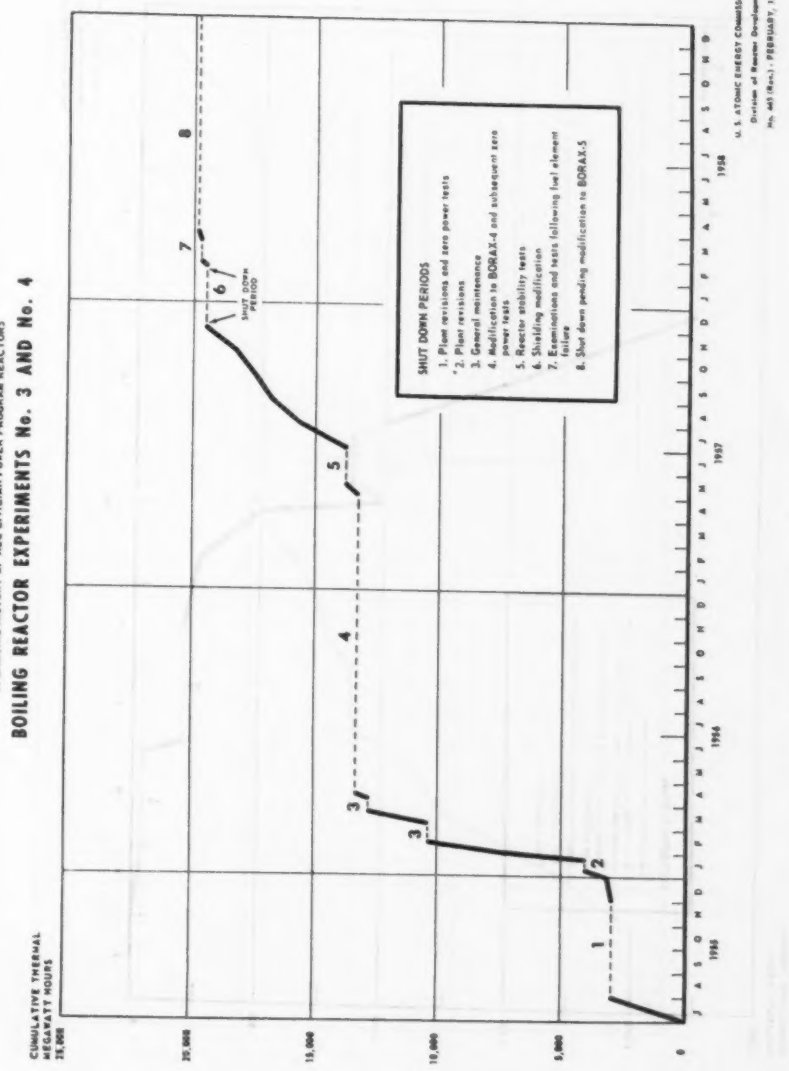
OPERATING HISTORY OF AEC CIVILIAN POWER PROGRAM REACTORS


OPERATING HISTORY OF AEC CIVILIAN POWER PROGRAM REACTORS
BOILING REACTOR EXPERIMENTS No. 3 AND No. 4
CUMULATIVE THERMAL MEGAWATT HOURS
25,000
20,000
15,000
10,000
5,000
0
J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1955
1956
1957
1958
SHUT DOWN PERIOD
SHUT DOWN PERIODS
1. Plant revisions and zero power tests
*2. Plant revisions
3. General maintenance
4. Modification to BORAX-d and subsequent zero power tests
5. Reactor stability tests
6. Shielding modification
7. Examinations and tests following fuel element failure
8. Shut down pending modification to BORAX-5
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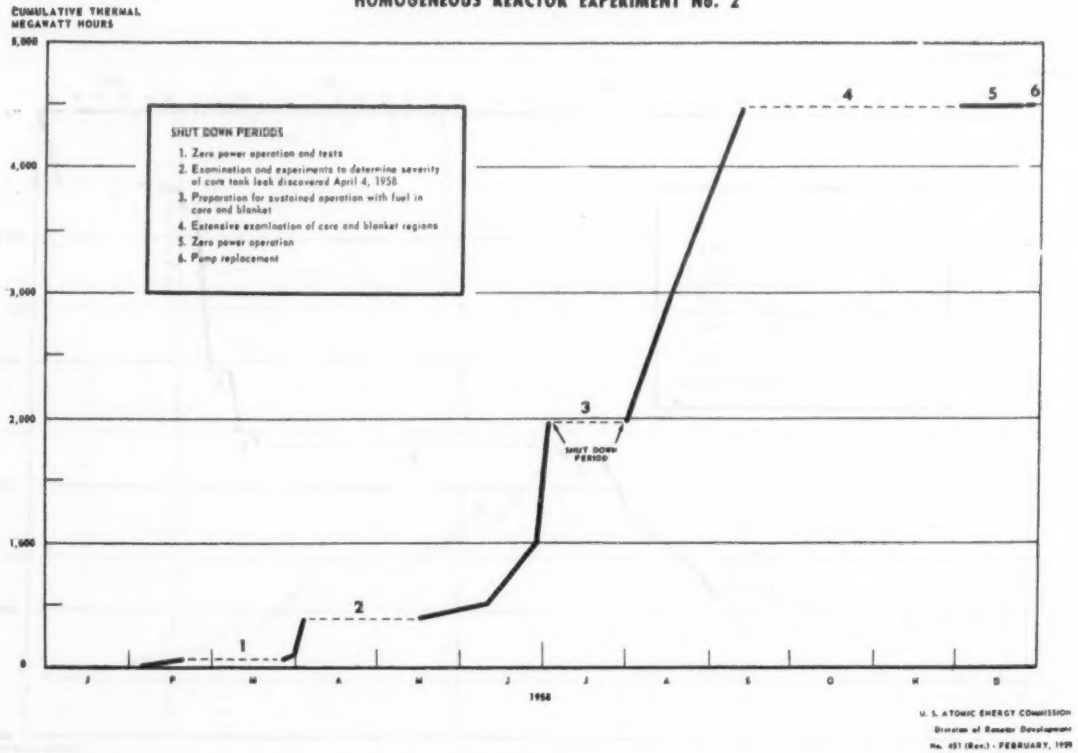
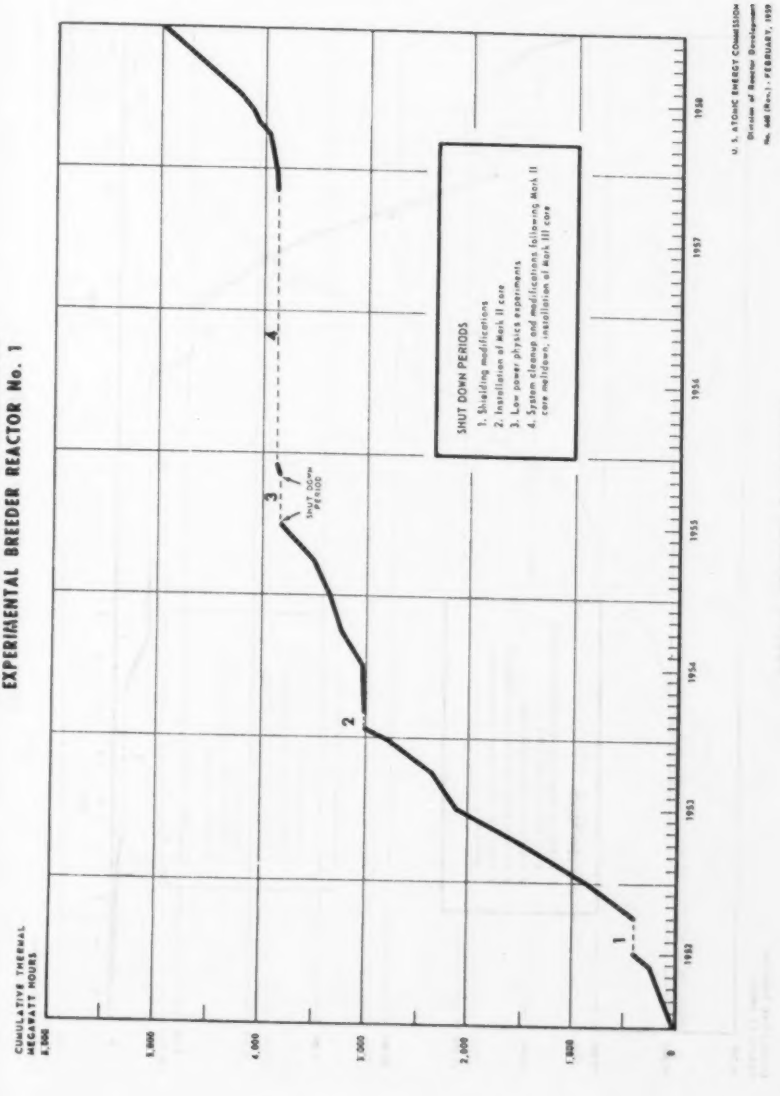
OPERATING HISTORY OF AEC CIVILIAN POWER PROGRAM REACTORS

HOMOGENEOUS REACTOR EXPERIMENT No. 2



OPERATING HISTORY OF AEC CIVILIAN POWER PROGRAM REACTORS

EXPERIMENTAL BREEDER REACTOR No. 1


OPERATING HISTORY OF AEC CIVILIAN POWER PROGRAM REACTORS
EXPERIMENTAL BREEDER REACTOR No. 1
CUMULATIVE THERMAL MEGAWATT HOURS
SHUT DOWN PERIODS
1. Shielding modifications
2. Installation of Mark II core
3. Low power physics experiments
4. System cleanup and modifications following Mark II core meltdown, installation of Mark III core
1952
1953
1954
1955
1956
1957
1958
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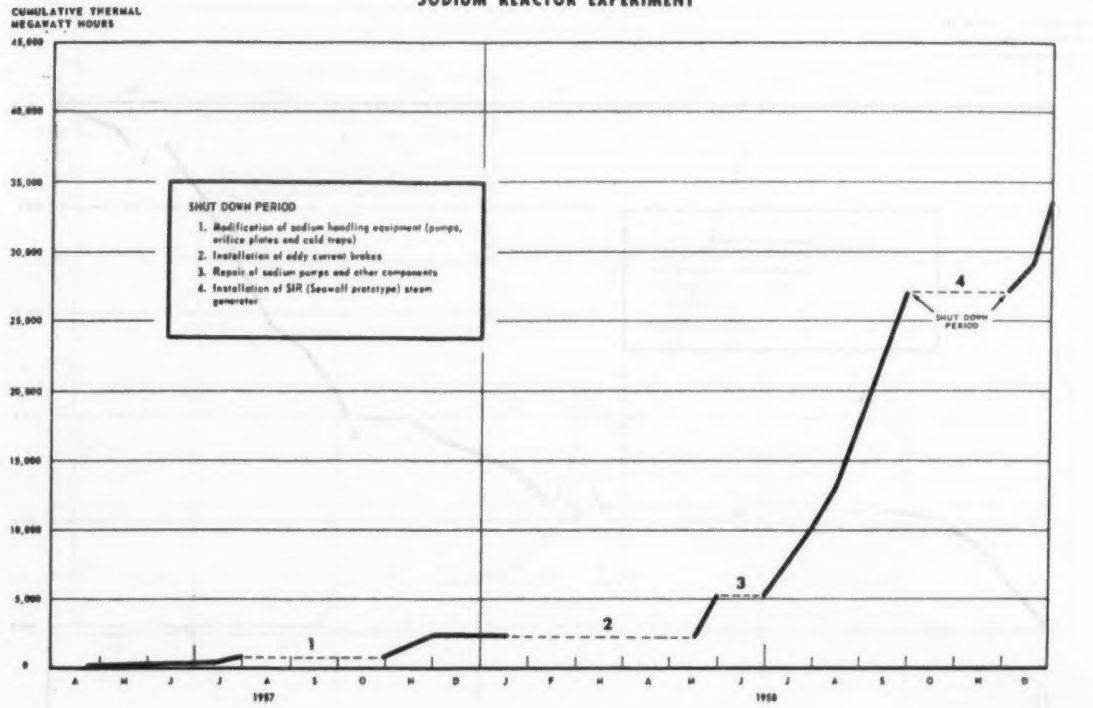
OPERATING HISTORY OF AEC CIVILIAN POWER PROGRAM REACTORS

SODIUM REACTOR EXPERIMENT



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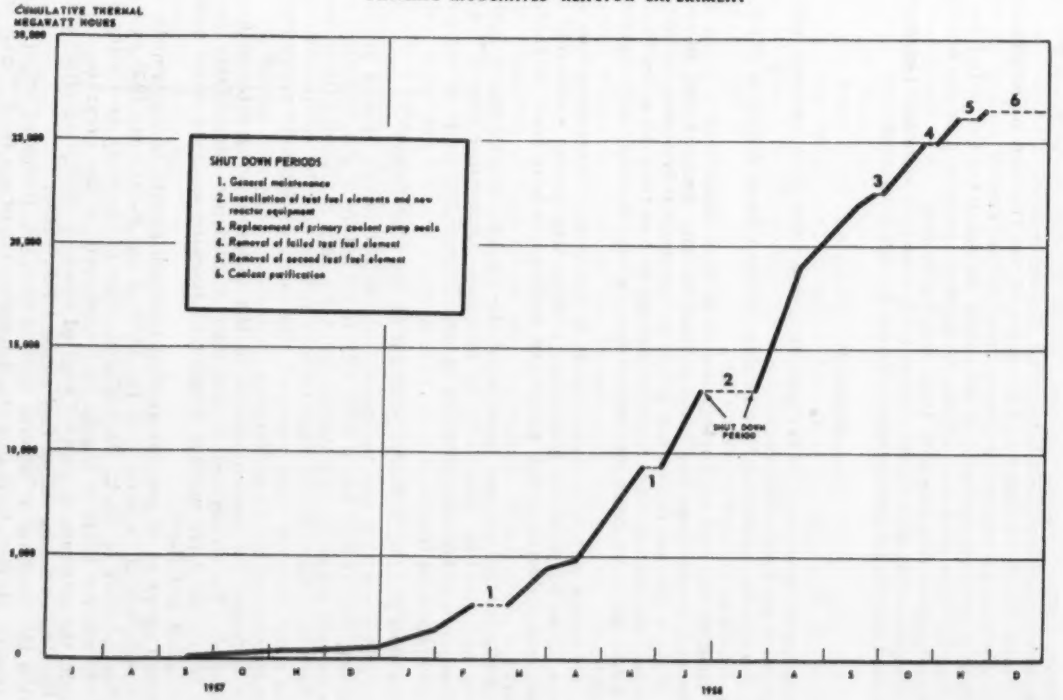
OPERATING HISTORY OF AEC CIVILIAN POWER PROGRAM REACTORS

ORGANIC MODERATED REACTOR EXPERIMENT

OPERATING HISTORY OF AEC CIVILIAN POWER PROGRAM REACTORS

ORGANIC MODERATED REACTOR EXPERIMENT



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No. 482 (Rev.) - FEBRUARY, 1959

APPENDIX 2

CIVILIAN NUCLEAR POWER

Report by Ad Hoc Advisory Committee on Reactor Policies and Programs, U.S. Atomic Energy Commission, January 2, 1959

MEMBERS OF AD HOC ADVISORY COMMITTEE ON REACTOR POLICIES AND PROGRAMS

James B. Black, chairman of the board, Pacific Gas & Electric Co.
Marion W. Boyer, director, Standard Oil Co. of New Jersey.
Harvey Brooks, dean of engineering and applied physics, Harvard University
Eger V. Murphree, president, Esso Research & Engineering Co.
Eugene C. Starr, Chief Engineer and Director of the Division of Engineering, Bonneville Power Administration, Department of the Interior
Robert E. Wilson, retired chairman of the board, Standard Oil Co. of Indiana
Henry D. Smyth (vice chairman of the committee), chairman of the board of scientific and engineering research, Princeton University
Alfonso Tammaro (chairman of the committee), Assistant General Manager for Research and Industrial Development, Atomic Energy Commission

SUMMARY

Objectives

The committee believes that the five principal objectives of the civilian nuclear power program in the United States are to—

(*a*) Fortify the position of leadership of the United States in the technology of nuclear power for civilian use;

(*b*) Reduce the cost of nuclear power in this country to a point competitive with power from fossil fuel at least in some areas within 10 years;

(*c*) Reduce the cost of nuclear power to the competitive point in friendly foreign nations having high costs for energy in less than 10 years through a comprehensive program of assistance clearly defined and vigorously pursued;

(*d*) Achieve a substantial reduction in the cost of nuclear power over the next 20 or 30 years by continuing studies which may ultimately lead to great cost reductions, but which are unlikely to bear fruit in the next 10 years;

(*e*) Make the fullest use possible of the nuclear energy latent in both uranium and thorium, especially by breeding, recognizing that U^{235} alone is probably not sufficiently plentiful to contribute significantly to our power needs over the long range.

Recommendations for the technical program in the near future

Our conclusions are that the technology of nuclear power is well advanced in this country, that it still has a long way to go before it can be turned over entirely to private industry, and that if the AEC leads a vigorous development program there is a fair chance that nuclear power may be competitive with power from fossil fuels in some parts of this country within 10 years and in most of the country within 20 or 30 years.

We have reviewed the present status of the technical program and find it generally sound. To strengthen it and give it guidance particularly in the immediate future we have made a number of recommendations, some general and some detailed, as follows:

(1) A broad program of general applied research should be generously supported by a substantial increase over the level of the fiscal year 1959 expenditures for this category of work. In addition, some of the work now being done under specific reactor projects should be transferred to this program.

(2) Within the program of general applied research, increased effort should be put on the fuel cycle, including fuel element fabrication.

(3) Within the program of general applied research, increased effort should be put on reactor physics, including the determination of eta for U^{233} and other similar constants.

(4) Construction of further prototypes[1] of boiling water reactors that advance the art should be encouraged. Studies being carried out by the Commission and by industry will probably indicate the desirability of constructing one

[1] Prototype is defined in this report as a pilot plant designed with the ultimate construction of a large plant in mind. See page 522.

or two of these prototype reactors starting in 1959. If further studies on pressurized water reactors bring forth promising new ideas, prototype reactors of this kind should also be constructed.

(5) Work on nuclear superheat should be directed toward incorporation of this feature in a prototype reactor at an early date.

(6) Work on pressure tubes and pressure tube reactors including that recently initiated is commended and should be continued, since this offers a possibility of unlimited reactor size and a promising method of achieving nuclear superheat.

(7) Since the concept of organic cooling looks attractive from the point of view of reducing capital costs, a further reactor experiment or prototype reactor should be started in 1959 if present design studies, particularly those on heavy water moderated and organic cooled reactors, come to promising conclusions.

(8) The general work on sodium as a coolant should be encouraged by continued operation of the sodium reactor experiment and by pushing the new development work on sodium systems. Construction of the Hallam plant is probably advisable but should be given a lower priority than the general work.

(9) The thorough investigation of a sodium-cooled and heavy water moderated reactor should be continued.

(10) Since there is need for a flexible reactor test facility and for experience with a gas-cooled, civilian power reactor at an early date, a reactor similar to that designed by Kaiser Engineers and ACF Industries should be constructed starting in 1959. Flexibility should be introduced into the design to make the reactor suitable for testing fuel elements for gas-cooled reactors at temperatures up to 1,400° F.

(11) Research and development support should be continued for the gas-cooled, heavy water, pressure tube reactor proposed by the Florida West Coast-East Central Nuclear Groups.

(12) Subject to the present technical review by the AEC, the Commission should support the research and development required for the advanced gas-cooled reactor proposed by the Philadelphia Electric Co. Support should also be continued on the somewhat similar concept of the pebble bed reactor.

(13) The aqueous homogeneous, molten bismuth, and molten salt reactors all offer the possibility of reducing the cost of the fuel cycle, and the last two offer the possibility of high temperature operation. These three concepts for power reactors should be critically compared and work concentrated on the concept that appears the most promising.

(14) Work on reactors involving the U^{233} breeding cycle should be reduced until it is clear that the value of eta is such as to make breeding feasible. Such breeding may require use of slurries, and work should continue on developing the technique of handling slurries.

(15) Work on plutonium as a fuel should be pushed and the necessary facilities for this work provided.

(16) Work on fast breeders should continue to receive vigorous support.

General recommendations

We believe that the objectives we have stated are probably attainable and are of great importance to this country. To attain them will require a vigorous and well-coordinated effort by Government and industry. In addition to the technical recommendations above, we make the following recommendations of a broader character:

(1) To promote better understanding of the U.S. nuclear power program, both in this country and abroad, the Atomic Energy Commission and the Joint Committee on Atomic Energy of the Congress should issue a formal statement of objectives, along the lines of those listed above.

(2) This statement should explain the necessity for leadership by the Federal Government, in cooperation with industry, and describe how this leadership is to be exercised.

(3) Possible methods of Government assistance in implementing the program should be examined with a view to maximum flexibility and minimum distortion of the technology.

(4) The United States should continue cooperation with and support of the International Atomic Energy Agency, Euratom, and other international programs, recognizing the fact that reactor development will proceed much more rapidly if different approaches are tried by different groups under different economic conditions but with full exchange of information.

(5) The technical program should give special emphasis to such factors as neutron economy in order to promote the most efficient use of fissionable and fertile materials.

(6) Prototype[3] reactors should be emphasized rather than large power reactors until the latter can be wholly or nearly self-supporting.

(7) Ad hoc committees such as the one here reporting should be appointed from time to time to review the program.

1. INTRODUCTION

Modern industrial civilization depends on sources of energy and the ability of science and technology to convert them to its needs. The discovery of nuclear fission just 20 years ago revealed a totally new source of energy. Discovered on the eve of war, this new power was developed in secret as a weapon of destruction to hasten victory over misguided nations seeking world conquest. Emerging from 5 years of catastrophic war, the world learned of uranium fission as a new source of energy already demonstrated in warfare and potentially a great addition to the world's sources of the energy so vital to the industries of peace. Uranium fission came to be regarded both as a symbol of the evils of war and as a panacea to cure all the world's ills.

It is inherent both in the nature of nuclear energy and in the history of its first use that its further development should concern statesmen throughout the world. In this country, the wartime developments were directed, coordinated and paid for by the Federal Government, although the actual work was done almost entirely by industrial or nonprofit organizations under contract. Since the war the pattern has remained the same for the military aspects of nuclear energy and to a great extent also for the peaceful aspects. In recent years an attempt has been made to transfer some of this responsibility for peaceful uses to private industry. Yet the difficulties and costs of the development of nuclear power have proved so great that the Federal Government continues to finance and to direct a large fraction of the activity. It is proper that the purposes, costs, methods and progress of this effort should be reviewed from time to time and that an attempt should be made to chart its future course. The present report constitutes such an attempt.

More specifically, the Committee here reporting was asked by the Atomic Energy Commission to—

> "(1) review the Commission's civilian power program;
>
> "(2) advise the Commission in connection with the formulation of a sound basic policy in the light of our current economy and the present stage of development of nuclear power technology;
>
> "(3) assist the Commission in establishing new goals and redefining the problems connected with the foreseeable expansion of commercial utilization of nuclear power and the concomitant development of a vigorous nuclear equipment manufacturing industry; and
>
> "(4) recommend immediate and long-range programs to achieve the Commission's new goals."

The Committee was further instructed to "take into consideration all relevant economic, political, and international aspects as well as the predominant technical factors involved in a viable nuclear power program based on U.S. national interests."

The Committee was requested to give specific attention to certain long-range programs outlined during the past year by the Atomic Energy Commission and by the staff of the Joint Committee on Atomic Energy of the Congress. There were some further detailed instructions which need not be quoted here (see appendix "B").

The members of the Committee were appointed late in September 1958, held their first meeting on October 3, and were requested to submit their report by December 1, extended at the first meeting to January 1, 1959. During the period between October 3 and January 2, the Committee has held 12 all-day meetings, in most cases paired on successive days. About half the meetings were devoted to briefings by the AEC staff, by representatives of the national laboratories or by representatives of industry. (See appendix "C" for a list of the briefings.) The other meetings were devoted to discussions of the technical and economic aspects of the program and the preparation of this report.

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[3] Prototype is defined in this report as a pilot plant designed with the ultimate construction of a large plant in mind. See p. 522.

Because of the shortness of time and the general familiarity of most members of the Committee with various nuclear power laboratories and installations, the Committee decided it could and must forego visits to the field.

The Committee recognized the importance of submitting a report by the beginning of January. We also recognized that we could not master this complicated field in 3 months, although all of us has some previous knowledge of nuclear power and its problems. There exists a vast body of evidence, some of it solid fact, some soundly reasoned prediction, and some of it uncertain extrapolation of inadequate data. Many of the facts which will determine the future of nuclear power have yet to be ascertained. In such a situation differences of opinion may be expected among reasonable men. Therefore, the members of our Committee initially agreed that our statements and recommendations would be adopted by majority vote. We are happy to report that this provision had to be invoked only on minor questions of wording or emphasis. We found ourselves in substantial agreement on all major points. We submit our judgments and recommendations as the best we can make in the time at our disposal. Perhaps more time would be of little help to us in studying the picture now before us, but we are sure that the lapse of years, or perhaps even of months, will change the picture substantially.

2. GENERAL OBJECTIVES OF THE PROGRAM

As we suggested in our introductory paragraphs, the nuclear energy program in this country and elsewhere is inextricably involved in the political, economic, and military policy of governments. In this report we are not directly concerned with the military aspect of nuclear energy. By our terms of reference we are concerned directly only with the civilian nuclear power program and specifically with the role the Atomic Energy Commission plays in that program. We are not even concerned with the peaceful application of nuclear fission other than the production of power. Since the AEC has so far dominated the power program, we shall consider the program as a whole without attempting to segregate that part of it conducted entirely by private industry.

If power from nuclear fission had proved to be very cheap and easily developed or, conversely, if power from conventional fuels were as expensive in this country as in some other parts of the world, private industry would have readily taken over the planning and construction of nuclear powerplants. In that situation the Government's role might have rapidly diminished to that of purveyor of nuclear materials (at least of those produced only in Government plants, such as U–235, heavy water, and plutonium), custodian of safety, and guardian against the illicit production of weapons.

Since the development of nuclear power is in fact proving to be difficult and expensive, the Government has been faced with a hard choice. Either this country continues its leadership at the cost of heavy expenditure or it accepts the probability that there will be no significant nuclear power industry in this country until the technology has been developed elsewhere and can be reintroduced here. This Committee knows of little support for the latter alternative.

Granted that we believe it important to proceed with the development of nuclear energy, we should define the objectives of our program and explain why such objectives are desirable. Both the AEC statement of June 3, 1958, and the JCAE staff memorandum of August 1958, mentioned in our terms of reference, have such statements of objectives, which differ from each other only in detail. We accept and endorse the three objectives listed in both of these documents but would like to add two others, which are explicit or implicit in the body of those statements. Before stating these three old and two new objectives in our own language, we wish to point out that all five are interrelated and that we attach little importance to the order in which we list them.

We believe the five principal objectives of the nuclear power program in the United States are to:

(*a*) Fortify the position of leadership of the United States in the technology of nuclear power for civilian use;

(*b*) Reduce the cost of nuclear power in this country to a point competitive with power from fossil fuels at least in some areas within 10 years;

(*c*) Reduce the cost of nuclear power to the competitive point in friendly foreign nations having high costs for energy in less than 10 years through

a comprehensive program of assistance clearly defined and vigorously pursued;

(*d*) Achieve a substantial reduction in the cost of nuclear power over the next 20 or 30 years by continuing studies which may ultimately lead to great cost reductions, but which are unlikely to bear fruit in the next 10 years;

(*e*) Make the fullest use possible of the nuclear energy latent in both uranium and thorium, especially by breeding, recognizing that U–235 alone is probably not sufficiently plentiful to contribute significantly to our power needs over the long range.

(a) U.S. leadership in technology of civilian nuclear power

The respect this country commands in the world today results on the one hand from our devotion to peace and freedom and on the other hand from our industrial and technical strength and the prosperity and military power that spring from it. While our scientific achievements may not have been remarkable, in technology we lead the world. Although we did not discover nuclear fission, we did put it to its first use, a military use in defense of freedom. For us to fall behind in developing the civilian use of energy from nuclear fission would raise doubts as to our interest in peaceful applications of this great discovery or as to our technological competence. Only the most sympathetic and sophisticated of our friends might recognize our lack of immediate need for nuclear power.

Some have suggested that this country has already "fallen behind in the race for nuclear power." This committee does not agree with such a point of view. We believe our knowledge of the technical and scientific problems of nuclear power has a breadth and depth that is unexcelled in any other country. We do not think that the number of kilowatts of installed nuclear power is a fair measure of the state of a country's nuclear technology. We are strongly opposed to a mere "kilowatt race." Nevertheless we recognize the vigor of the nuclear energy activities in the United Kingdom, Russia, and elsewhere. Unless we continue to pursue a vigorous program of research and development and continue to build some powerplants, we could easily fall behind.

(b) Competitive nuclear power in some U.S. areas within 10 years

The meaning of the phrase "competitive with power from fossil fuels at least in some areas within 10 years" should be defined. We mean that within 10 years utility executives facing the need for adding power stations to their systems might decide to build nuclear stations purely for economic reasons. Such a situation would not arise simultaneously in all parts of the country but first in relatively high cost fuel areas.

This country is fortunate in having large reserves of fossil fuels, particularly coal. Estimates of how long these fuels will last vary widely, depending as they do on predictions of increased use of fuel for electric power and other needs and of future discovery of additional reserves. How long our domestic oil reserves will last is uncertain, but in any case it is desirable to conserve them for other uses than the generation of electric power in central stations, which presently accounts for only about 3 percent of our consumption of petroleum products. Our coal will last much longer but it is not clear whether the cost of mining and shipping it may rise considerably. Were there no hope of bringing the cost of nuclear power into the general range of present costs for power from fossil fuel, it would be a waste of money to push the development of nuclear power for domestic reasons. Since there is good reason to hope that the cost of nuclear power may decrease over the next 10 or 20 years to the point where it is comparable to the cost of power from stations burning coal, a development program for domestic reasons alone is sensible, though not urgent. Whatever urgency there is in this development rises from our concern for national prestige and our desire to assist the development of nuclear power in other countries. There is, however, not a very great discrepancy between the program which might be laid out for domestic reasons alone and the program we are recommending.

(c) Competitive nuclear power in some foreign areas in less than 10 years

Ever since President Eisenhower's speech before the United Nations in December 1953, it has been the avowed policy of the United States to promote peaceful uses of atomic energy throughout the world. Initially it was thought that this policy might be implemented by encouraging the building of nuclear

power reactors both in underdeveloped countries and in those that were highly industrialized. With the passage of time it has become apparent that nuclear power stations in underdeveloped countries are not likely to be very useful in the near future. In contrast, the desire for nuclear power in the countries of Western Europe has been emphasized by the Suez Canal crisis. The Euratom agreements are a concrete recognition of these desires and of our interest in helping the nations in Western Europe to meet them. We cannot carry out our international obligations and help the development of nuclear power in other countries unless we have a continuing program of our own. Nor is our cooperation with other countries a one-way street. Our technology and the strength of our atomic power industry will be enhanced by the knowledge gained from the construction and operation of nuclear powerplants in areas where they are already nearly competitive with fossil-fueled plants.

(*d*) *Reduction in nuclear power costs over next 20 or 30 years*

A strict interpretation of the immediate objectives of competitive nuclear power in this country and elsewhere might lead us to concentrate on a type of power reactor which gave promise of meeting these objectives within the specified time limit. Yet there may be other types of reactors, not now far enough along in their development to meet the 10-year time limit, which will nevertheless ultimately give cheaper power from fission than those currently available. For this reason, our committee has added the explicit objective of ultimate low cost. We think this objective is implied in both the AEC and the JCAE programs, but we have heard the suggestion made that work on all types other than the one or two now well advanced should be dropped. Since we believe this would be a mistake, we will include in our program recommendations for work on certain types of reactors that we can hardly hope will be in general use within 10 years.

(*e*) *Fullest possible use of nuclear energy latent in uranium and thorium*

It is obvious that there would be no point in developing nuclear power if the supply of uranium were so scanty that it would run out after a few years' operation of a few full-scale powerplants. The known reserves of uranium have increased greatly in the last 5 years. Estimates of the future increase in these reserves are even more uncertain than similar estimates for coal and oil. If we assume that a large fraction of the new powerplants built after 1970 are nuclear plants and that our total needs for electric power increase as they have been recently, then the total nuclear capacity by 1980 or 1990 would be approximately equal to our present capacity for producing power from fossil fuel. If such plants depended on U^{235} alone and if we confine ourselves to uranium that can be recovered at approximately the present prices, U.S. reserves of uranium might begin to run out in a few decades.

In principle, we know that it is possible to use the far more plentiful U^{238} for power and also thorium. We know also that this can be done effectively only by the development of breeder reactors and that such development is extremely difficult. Consequently, we feel that the development of breeder reactors should be pushed vigorously, since otherwise we might find ourselves faced with a shortage of fissionable material by the year 2000. Successful breeding is the equivalent of multiplying our reserves by a large factor, which could be as high as 50 or 100, and should have a further consequence of lowering costs since all the nuclei in a pound of natural uranium would be potential fuel instead of only 1 or 2 percent.

We would like to point out two corollaries to this conservation objective. The first is that obviously U^{238} tailings from nuclear powerplants as well as from diffusion plants should be stored in the hope that they might eventually be used as fuel. The second corollary is the desirability of neutron economy in the design of powerplants. Neutrons lost by absorption in the moderator, coolant, or structural material can never be recovered, and constitute a waste of natural resources. In the interests of lowering costs or improving safety it may be necessary to use absorbing materials in reactors, but the basic importance of neutron economy should always be borne in mind.

At present the financing of nuclear powerplants usually involves some form of direct or indirect assistance. It is important that the form of this assistance should not artificially encourage the use of absorbing materials at the cost of neutron economy. For example, the waiving of a use charge for nuclear fuel encourages the designer to use cheap materials in the reactor itself to keep down

the unsubsidized capital cost and in the fuel elements to keep down the operating cost, even though such materials may be bad from the point of view of neutron economy and therefore waste the nuclear fuel.

3. GENERAL COMMENTS ON OBJECTIVES

As was suggested at the beginning of our statement of the general objectives for the U.S. nuclear power program, they are to a large degree interrelated. Certainly the maintenance of U.S. technological leadership depends on success in reaching several or all of the other four objectives listed. Objectives (b), (c), and (d), and even to some extent (e), are directed at lowering the cost of nuclear power although for different specific purposes and with different time schedules.

At present, nuclear power is too expensive both in terms of the capital costs of the plants and in terms of operating costs, including those of the fuel cycle. There is general agreement among reactor experts that both costs can and must be lowered. In the next section we will review various technical goals that might lead to the lowering of one or the other of these major cost items. The most optimistic estimates of capital costs per kilowatt for large nuclear powerplants presently range from $250 to $500 compared to the range of $125 to $200 per kilowatt of capacity for conventional plants using fossil fuels.

Operating costs vary even more greatly than capital costs with the type of plant and especially with the type of fuel cycle involved. They also depend greatly on the financial arrangements made for the fuel and on the value assigned to plutonium recoverable from the fuel. The cost of uranium itself is a major factor in the fuel cycle cost. In comparing cost estimates made by different groups both in this country and abroad, extreme care must be used in examining the accounting assumptions.

The fact that some governments in Europe finance the capital costs of powerplants leads to low fixed charges and tends to emphasize low operating costs at the expense of high capital investment. There are other factors that affect costs differently in this country and abroad. For example, the relatively low cost of labor in Europe may favor plants that require a great deal of field fabrication compared to central shop fabrication.

Political factors also are relevant to the choice of the type of reactor to be built abroad as compared to this country. Some countries have been reluctant to use enriched uranium and heavy water because of the dependence on the United States for these materials which such a choice presently entails. This reluctance seems to have diminished somewhat in the last year or two but may still be present to some extent.

Accepting the general objectives of the program, we need to relate them to the important technical factors that must be borne in mind in planning how these objectives may be attained. The next section of this report reviews those factors. The subsequent sections consider the various types of work that should be carried out to solve the technical problems (sec. 5), the present status of the program (sec. 6), recommendations for the technical program in the near future (sec. 7), long-range possibilities and program (sec. 8), cost estimates of the program (sec. 9), administrative implementation of the program (sec. 10) and general recommendations (sec. 11).

4. IMPORTANT TECHNICAL FACTORS

The cost per kilowatt hour of electricity from nuclear powerplants is divided between capital and operating costs, with the former being somewhat greater than the latter in most current estimates. The operating cost is mainly due to the cost of the fuel cycle. The magnitudes of the various cost components vary with reactor type and size but, to achieve substantial reductions in the cost of nuclear power, both fuel cycle and capital costs must be decreased.

In this section we review what we consider to be the important technical factors in seeking reductions in the cost of nuclear power. To some extent these factors are mutually contradictory, and an optimum design from the economic standpoint will involve some compromise between them. It seems likely, however, that any reactor system that is very deficient in any one of them will ultimately fail in competition for the cheapest power source. These factors are as follows:

(*a*) Simplicity and reliability of plant design;

(*b*) High specific power, in terms of heat generation per unit mass of fuel inventory, and high power density, in terms of heat generation per unit volume of the reactor;

(*c*) Low-cost fuel cycle, including a high irradiation level for the fuel and low fabrication and reprocessing costs;

(*d*) High thermal efficiency, implying a high exit temperature of the coolant;

(*e*) Favorable neutron economy, implying a high conversion ratio.

These technical factors interact in a complex way, and in many cases the goal of economic power in the short run may be in conflict with the objective of the cheapest power in the long run. For example, high thermal efficiency and high specific power call for the use of unconventional coolants such as sodium or high pressure helium. Because of the lack of commercially available materials and equipment for handling such coolants, the capital costs of systems employing them are presently high compared with those using conventional coolants like water. Nevertheless, these extra costs tend to decrease with increasing experience, as has already started to happen in the case of sodium. The cost of obtaining the necessary experience with an unconventional coolant may be extremely high and yet, unless this initial investment is made, the ultimate economic advantages of the new technology cannot be realized. The situation is even more acute in the case of fluid fuel reactors, where the advantage of very high specific power and low fuel-cycle costs must be weighed against the tremendous technical effort required to bring any fluid fuel technology to the point where it can even be assessed realistically in comparison with that of, say, heterogeneous, water cooled reactors.

Another example of the conflict of goals is the comparison of stainless steel with zirconium as fuel jacketing material. In the short run, considerations of simplicity and commercial experience favor the use of stainless steel, but this exacts a penalty in terms of higher fuel enrichment and lower conversion ratio and thereby significantly increases the cost of the fuel cycle. Such considerations suggest that zirconium will prove the superior material and that the costly fabrication experience needed to realize its economic advantages is probably justified.

Still another example is the use of heavy water as moderator in nuclear powerplants. This increases the capital cost, not only directed because of the cost of the heavy water but also indirectly because of the complexity of the equipment needed to prevent excessive losses of heavy water. Against this must be offset the excellent neutron economy of heavy water, offering the possibility of attaining very high irradiation levels with low enrichment material and thus achieving lower fuel-cycle costs.

In what follows we discuss briefly each of the important technical factors listed above.

Simplicity and reliability of plant design

This factor is directed mainly at the capital cost of the reactor, but has a bearing on the cost of the fuel cycle insofar as the complexity of the fuel elements influence their fabrication cost. The use of conventional materials of construction in the permanent reactor structure offers savings not only in the direct cost of the materials but also in the lower cost of fabricating inspecting and testing such materials. The principal attraction of the organic cooled reactor, for example, lies in the fact that organic coolants have a high boiling point and are noncorrosive against low carbon steels, thus permitting conventional steel construction with low pressure requirements. Against this must be offset the radiation damage to organic coolants and consequent makeup requirements, and the relatively poor heat transfer. In general high capital costs can be justified only by unusual gains in the other factors, especially the cost of the fuel cycle and the thermal efficiency of the steam cycle.

It is probable that further experience in building and operating nuclear powerplants will show that many of the rigid specifications now used can be relaxed. If safety, reliability and long life can be achieved with cheaper materials or more liberal manufacturing tolerances or both, the cost of power may be substantially reduced.

High specific power and power density

High specific power (power per unit mass of fuel) and power density (power per unit volume of reactor) tend to reduce fuel cycle and capital costs of nuclear

powerplants. When widely differing reactor types are being compared, power density may be more significant than specific power although both should be high. High power density implies good utilization of the fixed reactor structure and is particularly important for very expensive reactors such as fluid fuel types or fast breeders. The capital costs per installed kilowatt of such components as the shielding and the reactor container are reduced as the power density increases.

If the specific power can be increased only at the price of further subdividing the fuel, the cost of fabricating fuel elements increases and a point of diminishing returns is rapidly reached. As fabrication processes can be cheapened, the optimum size of fuel element gets smaller and the corresponding specific power becomes higher.

A major limitation in raising the specific power is the ratio of peak to average power in the reactor. In most power reactors operating on thermal neutrons this ratio is around 3, so that most of the fuel elements are not utilized to their maximum capability. This limitation can be partly overcome by zoning the reactor with respect to fuel element and moderator arrangements, although only at the price of increased core complexity. We believe that the possibilities of such zoning should receive increased study.

Low-cost fuel cycle

The irradiation level, measured in megawatt days per metric ton of uranium in the reactor, is an important factor in the cost of the fuel cycle. For a fixed cost of fabrication, the higher the irradiation level the lower the contribution of fabrication cost to the cost of power in mills per kilowatt hour. For example, the fabrication cost would be halved by doubling the irradiation level. For low enrichment fuels, however, there are other gains. For example, considerable plutonium is produced and burned inside the fuel element for high irradiation levels, and as a result there is a reduction in fuel burnup cost. This factor is of comparable importance in the case of fuel mixtures of enriched uranium with thorium because of the U^{233} generated in situ.

The factors that limit irradiation level depend upon the composition of the fuel. For uranium enriched in U^{235} above a few percent, the limit is determined essentially by radiation damage to the fuel, while for lower enrichments it is governed mainly by loss of reactivity due to burnout of U^{235} and the growth of fission product and isotopic poisons.

Fluid fuel reactors are mainly attractive as power reactors because they offer the possibility of extremely high irradiation levels combined with low fuel-cycle costs. This advantage depends on the fact that the allowable irradiation level is determined entirely by reactivity and not by radiation damage.

From what has been said, it is evident that the improvement of the fuel cycle is one of the most impotrant goals in reducing the cost of power. Lowering of fabrication costs not only reduces the cost of the fuel cycle itself, but may permit optimization of fuel element size for a high specific power and thus reduce capital costs.

Thermal efficiency

The overall thermal effiicency of the plant enters into almost all the cost components. For example, although capital costs are usually expressed in terms of dollars per electrical kilowatt, the actual cost of the plant is probably governed by its thermal capacity. Thus any increase in efficiency is reflected directly in the cost per installed electrical kilowatt. The burnup cost of the fuel is similarly affected by thermal efficiency.

Higher thermal efficiency implies higher exit temperatures of the coolant and hence higher operating temperatures for the fuel elements. If these higher fuel-element temperatures can only be achieved at the price of lower irradiation levels, as seems to be true in current designs of high temperature plants, both sodium and gas cooled, then the gain in thermal efficiency may be offset by the increased cost of the fuel cycle. This places a considerable premium on the development of better high-temperature fuel elements. In the case of sodium cooled reactors the use of oxide fuel with low thermal conductivity prevents the exploitation of the good heat transfer properties of sodium, while the use of high-conductivity metallic elements limits the irradiation level attainable. It is possible that the successful development of a carbide element would combine the advantages of high heat transfer with high irradiation level, and success in such a development appears necessary to making sodium cooled reactors look really attractive as power producers.

In the case of gas cooled reactors one must also take into account the energy lost in circulating the coolant, which is greater than in most other reactor types. An inspection of some current designs for gas cooled plants suggests that this factor may partially offset the advantage of the higher temperature cycle.

Currently the effort to raise the thermal efficiency includes the following lines of investigation:

(1) The use of fossil fuel superheaters with boiling and pressurized water reactors;

(2) The development of low cost schemes for achieving nuclear superheat in water cooled reactors;

(3) The development of high temperature, high pressure, gas cooled reactors;

(4) The development of sodium cooled reactors;

(5) The development of molten salt and liquid metal fuel reactors.

Scheme (1) is currently attractive because of the low cost of conventional fuel, and because this fuel can be utilized at very high thermal efficiency (greater than 50 percent) when employed for superheat only. This must be balanced against the cost of parallel capital installations. Also, from the standpoint of national prestige there is a certain weakness in this route.

It is believed that scheme (2) will have to be successful if water reactors are to be competitive with other types in the long run. Currently it appears that reactor designs employing pressure tubes may be more amenable to nuclear superheat than are pressure vessel types because of the greater ease of installing separate boiling and superheat regions, each optimized by itself. However, it is not yet certain whether feasible designs can be developed with low neutron absorption materials.

Scheme (3) is attractive provided that high enought gas pressures and temperatures can be used to achieve specific powers comparable with other reactor types. Scheme (4) is attractive provided that a suitable fuel element can be developed and a satisfactory solution can be found for the problem of separating incompatible coolant and moderator; these comments apply to both graphite and heavy water designs. Scheme (5) is the most radial and difficult.

Neutron economy

For purposes of discussion the neutron economy can be expressed in terms of the conversion ratio, the number of atoms of fissionable material produced per atom of fissionable material destroyed. It depends on the properties of the fissionable isotopes and on the absorption of neutrons by structural materials, coolant, fission products and other isotopes produced in the reactor. For high irradiation levels, very complex effects can occur due to the buildup of higher isotopes and the burnout of the new fuel generated.

Increasing the conversion ratio lowers the cost of the fuel cycle in the following four ways:

(1) For a given irradiation level, the amount of recoverable plutonium or U^{233} generated is increased.

(2) For low concentrations of U^{235} in uranium or of uranium in thorium, increasing the conversion ratio extends the irradiation life of the fuel.

(3) For low enrichment the regenerated fuel is partly burned, as well as the original fuel, and this leads to lower fuel burnup costs.

(4) An improvement in conversion ratio implies a reduction in parasitic absorption of neutrons, which in turn permits a reduction in the enrichment and hence in the cost of fuel.

All of these effects together result in a very substantial reduction in fuel-cycle cost with improved neutron economy, especially if fuels of low enrichment are used.

In considering the ultimate objective of maximum utilization of uranium and thorium reserves, the conversion ratio becomes of special importance and must exceed unity for breeding. The fuel burnup costs of breeder reactors are very low, but the principal motivation for breeding is the better utilization of raw material. Breeding in the plutonium U^{239} cycle is only possible in fast reactors. Ideally it would permit the conversion to plutonium and burning as fuel of all the U^{238} content of natural uranium. Furthermore, because of the positive breeding gain of the system, the total fuel inventory of the power economy increases at a rate governed by the so-called doubling time of the breeding cycle, so that the growth of the inventory can in principle match the growth of the demand.

However, it is the doubling time of the whole inventory rather than that of just the fuel in the reactor core which must be used as the basis for computing the doubling time. In fast reactors of current design the fuel and fertile material in the breeding blanket operates at very low average specific power, so that the effective doubling time is long. Moreover, the high inventory of fertile material needed for the blanket imposes an inventory requirement on total uranium resources, which makes the theoretically possible utilization of all the fertile material not realizable in a practical way consistent with the growth of the economy. It is clear that the fast breeder cycle must eventually incorporate a blanket of higher specific power and lower fertile material investment before this type of breeding can show its full advantages. In this connection the coupled thermal-fast reactor concept offers possible promise as a means for reducing inventory, increasing specific power and irradiation level, and coupling the plutonium fast cycle with the U^{233} thermal cycle in a single reactor.

Even if a practical and economic breeding cycle is not achievable, there is a considerable incentive for high neutron economy. For conversion ratios only slightly less than unity, especially if the new fuel can be regenerated within the reactor without reprocessing, the fuel burnup cost can be made extremely low, and as a result one can afford a considerably higher price for the raw material. This high fertile material utilization in internal conversion would open up the possibility of utilizing much lower grade uranium ores and would thus of itself increase our economic energy resources.

5. ELEMENTS OF THE TECHNICAL PROGRAM

In section 4 we discussed the general areas of reactor technology where progress is required if the cost of nuclear power is to be reduced significantly. To make such progress, activity is necessary in various types of research and development. The present section suggests the types of activity that should be carried forward.

(a) Basic nuclear, chemical and metallurgical research

Certain basic nuclear constants are still not as well known as is necessary for fundamental decisions. For example, the value of eta (the number of neutrons emitted per neutron absorbed) for U^{233} is still sufficiently uncertain to cast real doubt on whether or not a thorium U^{233} breeding cycle is practicable. We cite this merely to emphasize our point that much remains to be done in the field of basic nuclear research and of the nuclear properties of materials.

Even more apparent is the need to investigate further the chemical, metallurgical and mechanical properties of the materials that can or might be used in a reactor. It is essential to study the chemical and metallurgical processes that might be used in fabrication or in reprocessing of fuels. This includes the study of possible fuel materials, fuel element sheathing, coolants, coolant tubing, and so on. Some of this work is primarily chemical, some metallurgical, and some is concerned with ceramic materials. Both slurries in water and slurries in molten bismuth need to be further investigated if either the water or molten bismuth homogeneous reactor concepts are to be really successful. Although perhaps the bulk of the work on the effects of radiation comes under the head of development described below, certainly there remains much to be learned about the basic process of radiation damage.

In citing these fields in which research should be continued we do not of course suggest that development work and the construction of reactor experiments or even power reactors should await all the answers. Work on all of the elements of the technical program that we are describing in this section must be carried on concurrently.

(b) Component and process development

The importance of reducing the cost of the fuel cycle has been repeatedly emphasized by reactor experts. This involves the fuel elements themselves, their fabrication, and their processing after irradiation. The ideal fuel element is one that involves cheap materials easily fabricated, that will last a long time in the reactor giving high burnup, and that can be cheaply reprocessed. Unfortunately we have so far found these desiderata mutally incompatible, although this incompatibility does not seem to arise from any basic natural laws. Actual fuel elements so far developed are expensive to fabricate, often involve costly materials like zirconium, and have uncertain lifetimes. One of

the real uncertainties in our present situation is the lack of adequate statistical evidence on the lifetime of fuel elements that look promising from the point of view of sample tests. This is a difficulty that will diminish rapidly as more and more reactors are operated, but there must be enough reactor space available for fuel tests to give statistical results in the future. It must be remembered that it is difficult to combine routine operation of a power reactor with this type of testing. Facilities for inpile experiments must be extensive.

Similarly, processing of irradiated fuel elements on a scale large enough to give statistical performance data can provide more reliable information than laboratory processing of small samples.

We have cited various parts of the fuel cycle as needing further development. There also remains much to be done on other components of a reactor system such as the controls, pumps, heat exchangers, pressure vessels, pressure tubes and other equipment. Special equipment for remote operation and maintenance has been extensively developed but needs to be simplified and cheapened. One of the basic problems in choosing between reactor types is the relatives cost of remote maintenance necessary for a completely radioactive system such as exists in the momogeneous reactor comparted to the reprocessing of the highly radioactive fuel elements from heterogeneous systems. Again, we should emphasize the importance of inpile experiments.

(*c*.) *Conceptual design, evaluation, and cost studies of reactor systems*

In the past 10 years many of us have been exposed to glowing predictions of cheap nuclear power based entirely on paper studies of the costs of imaginary reactor systems. Generally speaking, the predicted costs have been directly proportional to the amount of available knowledge and inversely proportional to the optimism of the estimator. Nevertheless, we must recognize the value of such estimates when they are made objectively by competent scientists and engineers and when their assumptions are clearly stated. By combining various types of fuel element, coolant, and moderator it is possible to concoct several hundred schemes for reactor systems which might produce power. Obviously, it is impossible to build or even to design in detail more than a small fraction of such systems. But even in the light of 10 years of work there still remain some 20 or 30 different systems worthy of study. Many of them have already been studied fairly thoroughly. However, as improvements are made in technology a system that was entirely impracticable 5 years ago may be worth reevaluation. For example, if the price of beryllium could be very greatly reduced, its use as a moderator should be reexamined. This is only one of several examples that could be cited to suggest the importance of evaluations of new reactor concepts and reevaluations of old concepts in the light of new data.

Generally speaking, it is desirable to have any conceptual design that looks good examined by more than one group before extensive works is authorized.

(*d*) *Critical experiments and reactor experiments*

The initial idea for a new type of reactor is based on a combination of previous knowledge of the properties of the materials suggested and guesses as to the unknown properties and as to the behavior of the proposed system as a whole. To produce even a conceptual design requires elaborate theoretical work in terms of a specific lattice, fuel element, moderator, cooling scheme, and so on. Theoretical methods and nuclear data are not sufficiently reliable to make accurate predictions of neutron behavior. Even predictions of such basic things as critical mass are not entirely reliable. The first stage in testing theoretical predictions or in enabling them to be made with greater accuracy often involves setting up critical experiments. Such experiments have proved of great importance in the past and can be expected to continue to be valuable. In fact, it is generally desirable to do critical experiments before proceeding very far on the conceptual design of a reactor system.

The next step in testing an idea for a reactor system is a so-called reactor experiment. This would ordinarily follow a conceptual design study. The size of such an experiment and its degree of complexity varies greatly with the type of reactor that is under investigation. For example, the organic moderated reactor experiment that has been operating for about a year is a very simple and cheap device designed primarily to test the polymerization of the organic coolant and moderator. On the other hand, the second homogeneous reactor experiment at Oak Ridge is a very complete and expensive reactor system.

Reviewing the history of reactor development in this country, including production reactors and military reactors, it is clear that reactor experiments have

aimed at determining feasibility. A concept initially tested in critical experiments or "zero power" reactors then moves on to a reactor experiment which includes cooling and runs at a moderately high power level. The question at issue may be the arrangement of the fuel, the method of cooling, the control system, the variation of reactivity with temperature, or the possibility of breeding, to mention a few of the most interesting goals of past reactor experiments. Sometimes a simple concept proves feasible and is therefore important in estimating costs, as in the case of boiling reactors where a series of "quick and dirty" experiments was so successful. Generally, however, the results of reactor experiments are at most indicative rather than determining for estimates of costs. To the extent that successive reactor experiments have grown more complicated and more high powered, the data derived from them have become more useful to powerplant designers and cost estimators. Yet they remain essentially feasibility experiments and should be so regarded. They have one great advantage inherent in their name. No one expects them to produce cheap power or to be operated in a routine fashion. They are sources of information, not of power. There are several ideas for reactors now under discussion that appear to need reactor experiments before construction of larger units is undertaken.

The transition between reactor experiments and prototype reactors is a continuous one, as has already been suggested. In certain cases it may be possible to build a single reactor that serves both the purposes of a reactor experiment, such as those we have been describing, and of a prototype reactor, which we discuss more fully in the next section.

(c) Prototype reactors and full-scale power reactors

Reactor experts agree that nuclear powerplants of large capacity are more likely to give cheap power than small- or moderate-size plants. Two hundred to five hundred electrical megawatts seems to be the favored size. This poses a dilemma. Suppose a conventional powerplant in a given area produces power for 8 mills per kilowatt-hour, whereas estimates for a 200-electrical-megawatt nuclear plant are 9 mills per kilowatt-hour and for a 50-electrical-megawatt plant 11 mills per kilowatt-hour. If the estimates are right, the 200-electrical-megawatt plant will lose $200 for every hour of operation compared to $150 for the 50-electrical-megawatt plant. But the estimates may be wrong. If they are conservative, perhaps the big plant can do as well as a conventional plant; perhaps improvements after a few years' operation will even make it profitable whereas the smaller plant would always operate at a loss. On the other hand, if the true figures turn out to be 14 mills for the big plant and 16 for the small, figures which seem more realistic at the present time, then the losses are $1,200 per hour and $400 per hour, respectively.

Evidently if either plant is going to operate at a loss the only technical reason for building it is to get information and experience. Therefore, the question arises as to how much more information will be obtained from the big plant than from the small and how much is the increment of information worth.

To consider this question we need further definition. We would characterize the small plant we have been discussing as a prototype; i.e., a pilot plant designed with the ultimate construction of a large plant in mind. Preferably the prototype would be designed subsequently to or simultaneously with the design of a large plant. It would have the same moderator and fuel arrangement contemplated for the large plant, the same coolant and coolant system, the same type of fuel element, and insofar as possible the same pumps and other auxiliary equipment. Ideally a prototype would contain all the major components of a full-scale reactor. Such a plant might be more highly instrumented than a big reactor forming an important part of a power system. Though operating costs could be materially reduced by selling power, such a plant would not be an essential part of a power system. The big plant we are talking about, just by reason of its size and cost, would have to be part of a power system if it were to be operated without staggering costs.

We realize that the distinction between large-scale powerplants and prototype plants is arbitrary. A number of the plants now under construction or proposed as parts of power systems might be called prototype plants and might be run as such. Even the Shippingport plant, though unnecessarily large, might fairly be described as a prototype plant in terms of instrumentation and method of operation.

We cannot give a general answer to the question of weather nuclear power technology can be advanced more rapidly or more cheaply by emphasizing proto-

type plants rather than full-scale plants. The state of the art varies from one reactor type to another. Even the size of plant necessary to qualify as a real prototype varies from one kind of reactor to another. Nevertheless, we can cite a number of advantages of prototypes. For example, several "generations" of prototypes, each modified by experience with its predecessor, can be built for the price of a single full-scale plant. Generally prototypes can be built more rapidly and modified more easily. Site selection is easier. Because of lower capital cost it should be easier to get them financed by private industry.

The Committee believes that the burden of proof at this time is on the proponents of large powerplants. We think each such proposal should be examined carefully with respect to cost to the Government and cost to the consumer. Then the knowledge to be gained should be compared with that which a smaller prototype might furnish and balanced against the difference in costs.

6. APPRAISAL OF PRESENT STATUS AND PROGRAM

The present program for the development of power reactors in the United States is properly characterized as one of broad technical scope. The many areas of technology and combinations of techniques being explored in the program make it somewhat difficult to find a completely satisfactory order for review and appraisal of the program. Any system for the classification of reactors or nuclear powerplants appears to have deficiencies of one kind or another. For the purposes of this report it was decided not to introduce any particularly new classification system, but rather to adhere closely to the general scheme of budgetary documents and other reports of the AEC. Thus, the program will be reviewed under the major headings of (*a*) water-cooled reactors, (*b*) organic-cooled reactors, (*c*) liquid-metal-cooled reactors, (*d*) gas-cooled reactors, (*e*) fluid-fuel reactors, and (*f*) fast-breeder reactors.

Additional comments will be provided on plutonium fuel for reactors, power reactors for plutonium production, small power reactors, reactors for propulsion of merchant ships or for generating process heat, and test reactors. Then there will be an appraisal of general research and development with particular attention to work on fuel cycles.

We have not dealt with the subject of reactor safety or of utilization or disposal of radioactive byproducts of reactor operation, since these matters are under intensive investigation by other AEC committees.

Water-cooled reactors

The largest amount of research and development work has been devoted to nuclear powerplants using water-cooled reactors. This group has the heritage of experience with production reactors and naval propulsion plants. There are many interesting variations in the broad group of water-cooled reactors, including the choice of ordinary water versus heavy water, the degree to which boiling is permitted in the reactor core, and the selection of moderator. The fact that either ordinary or heavy water performs well as both moderator and coolant has resulted in frequent uses of water in both capacities in power reactor designs. The only serious work on water-cooled power reactors utilizing a different moderator has been that resulting from Hanford experience with graphite as moderator and ordinary water as coolant.

There is extensive experience in use of ordinary water as moderator and coolant, both without and with bulk boiling in the reactor core. Experience without bulk boiling derives from the naval program and from the Shippingport pressurized-water reactor; experience with bulk boiling derives from the borax series of experiments, the experimental boiling-water reactor, and the Vallecitos boiling-water reactor. Construction now in progress or committee[3] will extend and apply technology in these areas quite satisfactorily; additional plants are to be expected under terms of the agreement with Euratom. Advanced designs of powerplants employing pressurized-water and boiling-water reactors are being developed in studies that are proceeding in accordance with terms of the AEC Authorization Act for fiscal year 1959. These designs will take advantage of all completed research, development, construction, and operating experience to date. Water-cooled reactors should lead the transition toward private, com-

[3] Pressurized water reactors of the Yankee Atomic Electric Co. at Rowe, Mass., and the Consolidated Edison Co. at Indian Point, N.Y. Boiling-water reactors of the Commonwealth Edison Co. (Dresden plant) near Chicago, Ill., the Northern States Power Co. near Sioux Falls, S. Dak., and the Rural Cooperative Power Association at Elk River, Minn.

mercial exploitation and away from dependence upon Government assistance.

We believe that, within the next 4 to 6 years, experience with boiling-water and pressurized-water reactors will show how such reactors might be built to produce power that will be economically competitive or nearly so. This belief assumes that the reactors now under construction or authorized will be completed and that they may be supplemented by the construction and operation of prototype water reactors to test new ideas or technological advances. We doubt that the construction of additional large-scale reactors in itself advances the art sufficiently to justify the AEC in financing such construction. We recognize the reduction in power costs that multiplication of large reactors might bring through standardization and volume production, but believe that such construction should wait until prospective costs are sufficiently low (although perhaps not "competitive" as defined in sec. 2 above) to justify utility systems in paying for such construction.

On the basis of these views, we believe that the AEC should not furnish any construction funds for the building of more large-scale power reactors of the pressurized- or boiling-water types. AEC support of research and development should continue, with particular attention to improvements in the various elements affecting fuel-cycle costs. The success of these systems depends strongly upon the ability to reduce the costs of fabricating fuel elements and to increase irradiation levels. If significant new ideas are developed by some of the advanced design studies now in progress, or from other sources, the Commission should give consideration to aiding the building of prototype reactors to try out any technological advances considered to be sufficiently promising.

The water-cooled reactors of the United States all produce saturated steam at relatively low pressure (600 to 1,000 p.s.i. without superheat, compared with modern utility practice of over 2,000 p.s.i. with superheat). It is believed desirable to produce superheated steam more nearly in line with present utility practices. Superheat can be provided by fossil fuel for the present, but work on nuclear superheat should be included as an important part of the AEC development program.

In view of possible limitations on the size of pressure vessels for water-cooled reactors and in view of the potential importance of nuclear superheat, we believe that pressure-tube designs may have substantial promise for large nuclear powerplants. It is recognized that the advantages cited above for pressure-tube reactors must be weighed against the sacrifice in neutron economy resulting from additional structural material in the reactor core. Because of the importance of neutron economy, materials of low neutron absorption must be emphasized in the development program. It is noted that the present program does include two projects involving heavy-water-cooled reactors of the pressure-tube type. These are the plutonium recycle test reactor at Hanford and the Carolinas-Virginia nuclear powerplant. The present program also includes a dual-purpose reactor for Hanford, using graphite as moderator and water coolant in pressure tubes. The project of the Florida West Coast-East Central Nuclear Power Groups also involves pressure-tube construction, but with heavy water as moderator and gas as coolant. Assuming that this program will be carried to completion, the Committee believes that the Commission is devoting adequate attention to pressure-tube designs.

Heavy water is of particular significance as a power reactor component, in spite of its high cost, because of its low neutron absorption. The advantages of heavy water are most important in its role as a moderator. Construction of a heavy-water components test reactor is to be initiated at Savannah River in the current fiscal year; this reactor will be heavy-water moderated and cooled and will test fuel elements and system components.

Principal effort on power reactors using heavy water has appropriately been directed toward the goal of achieving operability on natural uranium fuel. A design study sponsored by the AEC is now underway with the objective of evaluating various designs of power reactors moderated with heavy water and operable on natural uranium. This work is expected to lead to a recommendation in the spring of 1959 regarding the desirability of proceeding with a demonstration project of this type. There is also a program for the development of natural uranium, heavy-water power reactors in Canada, and a reactor with a design capacity of 20 EMW is under construction there. We believe that international cooperation in this general area is especially desirable, since the use of natural uranium is of particular interest to foreign countries. We were pleased to learn that participation of other countries in the AEC-sponsored design study is contemplated.

Organic-cooled reactors

Organic-cooled reactors are closely related to water-cooled reactors since hydrogenous materials are involved in both cases. Because of the low vapor pressure and noncorrosive character of organic coolants, they provide a means for obtaining steam of quality equal to or better than that from present water-cooled reactors, with reduced pressure and less costly materials and equipment in the primary system. The absence of induced radioactivity in the primary system under normal operating conditions is an additional advantage. These various features lead to a simple and relatively inexpensive reactor system. Principal disadvantages in comparison with water-cooled systems are lower heat transfer coefficient and problems resulting from changes in composition of the organic material with temperature and irradiation.

Operating experience with the organic moderated reactor experiment in Idaho has led to considerable optimism that organic-cooled reactors may achieve economically competitive nuclear power in the short range. This experience is being used as a basis for designing a plant for the city of Piqua, Ohio, with a capacity of 12.5 electrical megawatts. Proposals for large-scale plants (150 electrical megawatts) also have been submitted in recent international competition. The principal advantages of organic materials are related to the coolant function; however, the hydrogen density makes these materials suitable substitutes for water as both moderator and coolant in the same reactor. A design study on an advanced organic-cooled reactor is underway for completion in the spring of 1959. This should provide a better basis for evaluation of this concept for large-scale application. In view of the nature of the OMRE and the limited objectives for which it was built, it has been proposed that a second, more flexible organic-moderated reactor experiment be built starting in fiscal year 1960. Such an experiment was described as somewhat analogous to the EBWR of the boiling-water development program. We believe that final plans and a decision to build such a reactor experiment should await results of the current design studies. These design studies include consideration of a heavy-water moderated, organic-cooled reactor, which may be especially promising.

Liquid-metal-cooled reactors

The eventual development of fast-breeder reactors, which will permit utilization of a major fraction of the fission energy available in natural uranium, apparently will be dependent upon success in the development of large sodium-cooled systems. A strong overall program for development and testing of components of a large-scale sodium system is therefore an essential part of a strong development program for fast-breeder reactors. The separate program recently established for development of such components suitable for use in systems with exit temperatures of 1200° F. appears to be appropriately timed. It will provide data valuable to the development of sodium thermal reactors as well as fast-breeder reactors.

A point of some concern in the sodium graphite development program is the design compromises resulting from the time schedule imposed on design and construction of the plant at Hallam, Nebr., for Consumers Public Power District of Nebraska. In particular, the large amount of stainless steel in the reactor core for separation of graphite and sodium gives poor neutron economy and requires high enrichment. It is recognized that compromises are always involved in fixing designs against construction schedules and that plants would never get built if designers were allowed to continue to make modifications as new information became available. In this case, however, it might be more profitable to explore design changes than to proceed immediately with this large construction project. We find it difficult to balance this possible advantage of delay against the desirability of getting additional experience with a large sodium-cooled system at an early date. Development of the sodium graphite system should attempt to improve neutron economy without sacrificing the advantage of high temperature. The question is whether such development is best carried out in the sodium reactor experiment at Santa Susanna, Calif., or in the Hallam plant at the cost of some delay in design and construction. The AEC has just received a report on the sodium graphite program from a special task force, but we have not had time to study it. In any case we urge the continued operation of the SRE and the frequent reevaluation of the whole sodium graphite system with particular reference to neutron economy and fuel-cycle cost.

One direction of the development effort aimed at improvement in neutron economy is the investigation of sodium-cooled reactors designed to operate on the

thorium U^{233} fuel cycle with neutrons primarily in the intermediate energy range. Information on the nuclear constants of U^{233} and associated products for this cycle is not adequate at present to make a definitive judgment on the merits of this concept, but from currently available information we do not see much to be gained by this approach.

The use of sodium coolant with heavy-water moderator is also being investigated. Since each of these materials is very well suited to its function, the combination is of considerable interest. The principal disadvantage is the chemical incompatibility of water and sodium. As a result of a proposal (under the second round of the power demonstration reactor program) from the Chugach Electric Association of Anchorage, Alaska, and the Nuclear Development Corp. of America, the AEC is supporting some experimental and preliminary design work on a reactor cooled with sodium and moderated with heavy water. We believe that support of this work is well justified.

One of the merits of the sodium heavy-water reactor is the possibility that, in a large size, it can operate on natural uranium. A design study of heavy-water-moderated power reactors operating on natural uranium will be completed in the early spring of 1959. The results, together with the design evaluation of the Chugach-NDA proposal, will provide an excellent opportunity for weighing the merits of sodium cooling against the design and operating problems imposed by chemical incompatibility with heavy water. We believe that a determination of future support of the sodium heavy-water program should be made as soon as the results of these studies are available, and we understand that this is in accordance with present AEC plans.

Gas-cooled reactors[4]

Gas-cooled reactors have reached a stage of development and demonstration (principally in the United Kingdom) such that they must now be considered important candidates for achieving economically competitive nuclear power in the short range. They also appear to have considerable development potential for going to very high temperatures and somewhat lower net power costs.

On the basis of present technology, it appears that gas-cooled reactors are high in capital cost and low in fuel cost compared with water-cooled reactors. The relative advantages of the two thus will shift in different economic frameworks.

Intensive effort in the United States on gas-cooled reactors for civilian power was resumed less than 2 years ago after a lapse of about 10 years. There has been a continuing exploration of the technology of gas-cooled reactors as part of the programs for development of military reactors. The Committee believes that the civilian power program of the United States should include a major effort on gas-cooled reactors. The effort of the United States should be aimed at producing temperatures of more than 1,000° F. This is in agreement with the present direction of the program. There are three major projects or proposals that are directed toward the development of gas-cooled reactors for stationary nuclear powerplants:

(*a*) The proposal of Florida West Coast-East Central Nuclear Groups working with General Nuclear Engineering Co. to develop, design, construct, and operate a carbon dioxide cooled, heavy-water moderated, pressure-tube reactor of 50-e.m.w. capacity. This proposal has been accepted by the AEC. This plant would be a prototype of a larger (200-e.m.w.) plant, which could operate on natural uranium.

(*b*) The gas-cooled, graphite-moderated reactor being designed for the AEC by Kaiser Engineers and ACF Industries, with an output of 30 electrical megawatts using partially enriched uranium dioxide fuel clad in stainless steel. This reactor is designed for use of helium as coolant at 1,000–1,200° F. exit temperature, but can also operate with carbon dioxide at some sacrifice in capacity.

(*c*) The proposal of Philadelphia Electric Co. in collaboration with General Atomics, Bechtel, and approximately 50 privately owned utilities to develop, design, construct, and operate a helium-cooled reactor of 30- to 40-electrical-megawatt capacity with fuel consisting of a mixture of enriched uranium carbide and thorium carbide in graphite.

[4] Mr. Black did not participate in the consideration of gas cooled reactors inasmuch as Pacific Gas & Electric Co. is a participant in the proposal of Philadelphia Electric Co. and associates.

In addition to the three major projects or proposals listed above, the AEC has supported modest effort on development of technology for and resign evaluation of a system that would use graphite balls containing a mixture of uranium and thorium carbide as fuel. This concept often is referred to as the pebble bed reactor.

We believe that the status of development of gas-cooled-reactor technology in the United States warrants the early construction of a flexible reactor test facility, which could be used to test sections of advanced cores for high-temperature, gas-cooled reactors. The plane designed by Kaiser Engineers and ACF Industries could provide such a test facility and, in addition, could provide operating experience with a gas-cooled, civilian power reactor on the shortest possible time schedule.

The FWCNG–ECNG project is considered important as a reactor type with promise of producing economically competitive nuclear power in the United States using natural uranium as fuel, because of the low neutron absorption of heavy water.

The reactor type proposed by the Philadelphia Electric Co. and associates is considered the most advanced and the most speculative in terms of established technology. The fuel materials involved are the same as in the pebble-bed reactor. The essential idea involved in both concepts is the incorporation of the graphite moderator with the fuel, permitting high irradiation levels, high specific power, and high temperature. If either concept continues to prove attractive after further research and development, the resulting reactor would represent a great advance in technology.

Fluid fuel reactors

There are two principal reasons for interest in fluid-fuel reactors. One of these is to supplement the preponderance of work on heterogeneous or solid-fuel reactors to give added insurance for achieving low-cost nuclear power through high temperature or simplicity of the fuel cycle, or both. The second reason is that fluid-fuel systems appear to offer the only possibility for thermal breeding on the thorium U^{233} fuel cycle with an acceptable doubling time—say 10 years or less. Uncertainties in the value of eta (the number of neutrons emitted per neutron absorbed) make it impossible to give positive assurance that breeding on this cycle can, in fact, be achieved. The Committee strongly recommends that urgent effort be devoted to measurements of eta for U^{233} by various laboratories and by various methods.

Until better knowledge of eta is obtained, work on thermal breeders should be held to a minimum. However, development of a thermal breeder reactor, if shown to be feasible, should be included as part of the overall program at approximately the present level of effort on the aqueous homogeneous project. Based on present information, breeding with the thorium U^{233} cycle is uncertain for aqueous homogeneous reactors, even more uncertain for liquid-metal-fuel reactors, and not possible for molten-salt reactors.

Of the three fluid-fuel reactor types, the aqueous homogeneous is of interest as a breeder and because of its simplified fuel cycle, the molten salt is of interest because of high-temperature operation and simplified fuel cycle, and the liquid bismuth because it might incorporate all three advantages. All three types, particularly the liquid bismuth, present many difficult development problems. For example, it is probable that, for successful breeding in the aqueous homogeneous or in the liquid bismuth reactors, a slurry will have to be used at least in a blanket, and the development of adequate slurry technology is a very difficult job.

The three fluid-fuel systems should be evaluated first as to promise for producing low-cost nuclear power and not more than one project supported on the basis of that objective. When additional information on the value of eta for U^{233} is available, the situation with respect to thermal breeding should be reexamined, with a view toward increased support. We see no present basis for the construction of fluid-fuel reactors of any of the three types.

Fast-breeder reactors

On the basis of present estimates of uranium reserves, breeder reactors eventually must be developed if nuclear-fuel resources are to play a major part in supplying energy for the world for more than a few decades. In the case of uranium, breeding can only be accomplished with a reactor operating on fast neutrons. This situation has led to major development efforts on fast-breeder reactors in the three strongholds of nuclear technology—the United States, the

United Kingdom, and the Soviet Union. The cooperation between the United States and the United Kingdom on fast breeders has been very useful and should be continued and expanded.

While there is widespread agreement on the ultimate need for development of fast-breeder power reactors, there is not agreement on the required time scale for that development. Judgments of the time at which breeders must be developed depend upon judgments of increases in energy demands, of fossil-fuel reserves and economics, and of nuclear-fuel reserves and economics. Each of these judgments is subject to much speculation and uncertainty. Information presented to the Committee makes it appear prudent to press the development of fast-breeder reactors on a schedule that would contemplate commercial, competitive operation before the end of this century. In view of the uncertainties in scheduling research and development and in view of the benefits to be derived if the achievement of breeding is advanced, the present fast-breeder reactor development program of the United States appears adequate and well timed. We do not believe that a "crash" effort on development of breeder reactors is warranted. We do note, however, that breeder reactors may lead to production of low-cost nuclear power at a date earlier than required from the standpoint of fuel resources. We also note that there may be considerable prestige value in early development of breeder reactors.

In view of the ultimately necessary role of plutonium as fuel in fast-breeder reactors, it is perhaps a weakness of the present program that emphasis has been on initial operation with U^{235} as fuel. It is recognized that a plutonium loading for the EBR–I was delayed by the meltdown of that reactor's core and that plans are now being made for future operation with plutonium both in EBR–I and as a second core of EBR–II. It must be recognized that the achievement of economic breeding and the achievement of economic power utilizing the plutonium output of breeders both depend critically upon the development of means for handling plutonium fuel elements at reasonable cost. Therefore, we believe that the program will be strengthened as the use of plutonium fuel is given more serious and direct attention in the power reactors involved.

In theory, one region of a reactor operating on fast neutrons could be coupled with another region operating on thermal neutrons, with the result that the breeding gain would be characteristic of a fast-breeder reactor and the prompt-neutron lifetime would be characteristic of a thermal reactor. Results of recent critical experiments have indicated substantial agreement between theory and experiment. These data have given encouragement to the development of a fast-reactor system with a reduced inventory of fuel and fertile material, increased specific power and irradiation level, and hence shorter doubling time and lower fuel-cycle cost. We believe that this work should be pursued as part of the fast-breeder program.

Plutonium fuel for reactors

It is important to develop means of using plutonium as a reactor fuel. This will be essential for fast-breeder reactors and can reduce requirements for enriched uranium in nonbreeding reactors. The plutonium recycle test reactor under construction at Hanford should provide valuable information on the irradiation behavior of plutonium fuel elements. The plutonium cores planned for EBR–I and EBR–II should also provide useful data. Work at the Argonne National Laboratory on pyrometallurgical processing of irradiated plutonium, with some of the fission products left in the metal as alloying agents, is very interesting and promising. Investigations by Los Alamos, Argonne, and Hanford of the basic properties of plutonium and its compounds and alloys and methods of utilizing them in reactors should continue and, where feasible, be expanded.

Power reactors for plutonium production

Most types of nuclear power reactors now under consideration generate plutonuim, and therefore there is a relationship between military requirements for plutonium and civilian power development. If there is a need for increased plutonium production for weapons, to meet a portion of that need further consideration should be given to the construction of power reactors with participation by utilities.

The time required to design and arrange for construction of power reactors would undoubtedly be greater and the certainty of the plutonium output would be less than for production reactors having designs similar to those for which there is operating experience. Optimization of design and operation of reactors

will be different for plutonium production than for power generation. The capital cost and the fuel-cycle cost for a given plutonium output would be considerably greater for power reactors than for production reactors; the difference would have to be justified by revenue from the sale of power and by contributions to the advance of power-reactor technology. One such contribution could be the demonstration of reductions in fuel-cycle costs resulting from standardization and from volume production and processing of fuel elements for power reactors. Increased requirements for plutonium may therefore offer an opportunity to gain technology pertinent to power reactors at some incremental cost.

Small power reactors

The civilian nuclear power program has been considered primarily from the viewpoint of developing technology for large-scale power reactors having capacities above 100 electrical megawatts. The design, construction, and operation of prototypes on a smaller scale is an important part of that development program. These prototypes will also be important contributors to the development of power reactors with capacities of tens of electrical megawatts.

In general, we believe that nuclear power will first become economically competitive in large-scale plants. We recognize, however, that smaller plants may be important in particular geographic, economic, and political situations. We recognize further that neither the civilian prototypes nor the military small-scale plants are addressed specifically to the problems of achieving economically competitive power in small civilian stations. Therefore it may be desirable in the future, as design and economic evaluations proceed, to build additional demonstration plants for this purpose. We believe that the small plants now under construction or planned are adequate for the present.

Reactors for other civilian applications

Nuclear plants may be used to provide energy in forms other than electricity. One such application is the nuclear propulsion of merchant ships, which would have the advantage of making space presently used for fuel storage available for cargo. Special problems for a marine reactor are operation under conditions of ship motion, continuity of operation, capability of providing for fast maneuvering on demand, space limitations, and safety in close proximity to crew, passengers, and, at times highly populated areas. A pressurized-water reactor is being installed in the merchant vessel, NS *Savannah*, which should be in operation in mid-1960. A study is being made of the installation of a boiling-water reactor in a large tanker. In addition, there is a development program on a gas-cooled reactor that would be suitable for merchant-ship propulsion.

Another application of nuclear plants is to provide process heat. Market studies made under AEC contracts indicate that about twice as much fossil fuel is used to generate process heat as to generate electricity. A great portion of the process heat is used below 380° F., and there would be little difficulty in building reactors to supply this need. However, most of the process heat is consumed in relatively small blocks, 96 percent being less than 75 thermal megawatts and the median being about 10 thermal megawatts. The present high capital costs of nuclear reactors makes it difficult for them to compete in this area. Nuclear reactors also have a potentiality of providing high-temperature process heat, and work is being done by the AEC in cooperation with the Bureau of Mines on a helium loop operating at 2,500° F. The AEC is also cooperating with the Office of Saline Water, Department of Interior, in formulating a demonstration project on the use of a nuclear heat source for distillation of sea water. Nuclear plants to provide space heating do not appear attractive for general application because of the dispersion of consumers and very low load factors.

We have not had time to consider in any detail the applications of reactors for propulsion or for process and space heating, but we believe that the programs and studies in progress are adequate for exploring these areas at the present time.

Test reactors

The materials test reactor (MTR) at the National Reactor Testing Station in Idaho has been in operation since August 1952 and has been the principal U.S. installation for irradiation testing. The Canadian Government has made valuable irradiation space available in the NRX reactor and recently in the NRU reactor at Chalk River. The engineering test reactor (ETR) in Idaho, which attained full-power operation at 175 thermal megawatts in April 1958, provides facilities for large-scale tests. All of the irradiation space, particularly that suitable for the installation of loops, in these reactors is already assigned to

civilian and military projects. A study has been made and development work is being done for the AEC on an advanced engineering test reactor with a thermal neutron flux about twice that of the ETR.

The AEC, anticipating the need for additional test reactors beyond the MTR and ETR, in November 1956 announced a policy of fostering the construction of test reactors by industry. At the present time, the General Electric Co. and the Westinghouse Electric Corp. are each constructing a test reactor. Because of the current need for additional facilities, the AEC in October 1958 invited industrial, research, and educational institutions to submit proposals by January 12, 1959, for the performance of test irradiation services for the AEC. If suitable responses are not received, the AEC may have to build additional test reactors. The Committee believes that whatever steps are necessary should be taken to provide adequate irradiation space, which is of great importance for continued progress in the reactor development program.

The plutonium recycle test reactor and the heavy-water-component test reactor already mentioned will introduce a somewhat novel type of reactor into the program. These are test reactors, but in a different sense from the MTR and ETR, which are really radiation exposure reactors. Other reactors of the new type may be needed to test specific features of proposed reactor systems.

General research and development

It is only when an attempt is made to develop, design, build, and operate a nuclear reactor or powerplant that all of the many complex problems involved must be faced. Stytems with little experience behind them tend to look better than systems that have had sufficient work done to highlight the difficulties. Nevertheless, a balanced program must give recognition to the general as well as the specific. There must be stimulation of novel and unique ideas and willingness to drop old projects that have not lived up to expectations in favor of new developments with better prospects.

General research and development contributing to advancement of power-reactor technology is supported by the AEC both as part of specific reactor projects and as separate programs. The annual dollar support for both of these areas together is approximately one-third of the total annual operating expenses for the entire civilian reactor program. General research and development includes work on (1) advanced reactor designs, (2) reactor physics, (3) reactor materials, (4) reactor components and instrumentation, (5) reactor safety, (6) test reactors, (7) fuel element fabrication and reprocessing, and (8) waste disposal or utilization.

The fields of research mentioned above and discussed in sections 5 (a), (b), and (c) have a bearing on general reactor problems. Most of this work is carried out in the national laboratories, principally in Oak Ridge and Argonne. Some of this work is carried out under contract with organizations such as Battelle Memorial Institute, Iowa State College, and various other universities, and an increasing amount is being undertaken by industrial concerns that have acquired facilities and personnel for this work. Although the major portion of the work directly related to reactor technology is supported by the AEC Division of Reactor Development, some work on physics, metallurgy, and chemistry relevant to reactor problems is supported by the AEC Division of Research.

Under the general research program, advanced reactor designs and promising new concepts, such as fluidized-bed reactors and mercury-cooled fast reactors, are being investigated. (See app. D for a list of reactor design studies.) We believe that the present system for receiving and evaluating proposals seeking AEC support for such preliminary design and development studies is generally sound and adequate.

Work on reactor physics is generally carried out in two ways. Nuclear cross sections and other physical constants are measured by university groups as well as national laboratories. In addition, exponential and critical experiments providing basic understanding of reactor parameters are usually undertaken by national laboratories or industrial groups. We note that certain nuclear constants are still not as well known as necessary, particularly the eta values of U^{233} and U^{235}. Although much has been done in these areas and more work is contemplated, the importance of this work to reactor technology cannot be overemphasized.

In the field of reactor materials, fundamental investigations are underway on the behavior of various reactor materials under corrosive conditions in radiation fields. Work on the behavior of graphite, the development of new alloys

of increased strength and reliability, and the use of additives in coolant streams to extend the life of construction materials are all important parts of the general research and development effort. The present efforts, although commendable, could profitably receive additional support, particularly with respect to methods of material fabrication.

Under the program of reactor components and instrumentation, the AEC is supporting work directed to a better understanding of heat transfer. The development of thermal shock resistant materials and other engineering aspects of reactor components and instrumentation are also receiving attention. The proposed expansion of this effort as a general research item and specifically as outlined with respect to the sodium components development program is desirable. Continued attention and emphasis should be given to the development of lower cost and more reliable components.

Much work is presently underway on reactor safety. The SPERT facilities investigating-water reactors, the KEWB facilities investigating aqueous solutions, and the TREAT facilities investigating behavior of fast systems all are extremely worthwhile. Consideration should also be given to expanding the safety work with respect to other reactor concepts presently receiving attention, such as organic-cooled reactors and gas-cooled reactors.

The test reactor program has been discussed in the previous subsection.

We noted with considerable interest the plans of the AEC for expanding work on nuclear fuel cycles. It is particularly in this area of fuel-cycle development that there is need for an open mind to new ideas. There are variations in fuel-coolant-moderator arrangements that other countries (notably the Soviet Union) have exploited with apparent success and on which little experimental work has been done in the United States. We hope that such ideas will be tested either in the expanded fuel-cycle program or as part of the basic development effort of the AEC.

Two facets of fuel-cycle development were given special consideration: (*a*) the economic effects of increased volume and (*b*) the balance of effort between general work and that related to specific projects. We were impressed by unit cost experience in the AEC production program as a reflection of costs that might be achieved if comparable volumes could be attained in the fuel cycles of power reactors. We believe that at some point it will be necessary for the AEC to take positive steps to stimulate some standardization of fuel elements and fabrication techniques in order to foster economies of increased production volume.

Work on methods of utilization and disposal of radioactive byproducts of reactor operation is important and is progressing but has not been examined by this Committee.

The distribution of support among the various technical areas in general appears properly balanced. The heaviest attention is being given to fuel-cycle technology. Such emphasis appears appropriate in view of the reliance of the entire program on this particular field. The total support of general research and development is somewhat less than would be desirable. There is also a potential danger in the present situation where an appreciable amount of general research and development is carried on as parts of specific projects. If the specific project is terminated for any reason, this work of general importance may also then be terminated. To avoid this danger and to give more flexibility, some of the general research carried out under specific projects should be transferred to the general program.

The Committee also has the impression that the present methods for program control, reporting, and accounting place undue demands on the time and energy of key technical personnel. In particular, it is the consensus of the Committee that the national laboratories should play a leading and responsible role in general research and development. Program direction and financial controls of the AEC and laboratory management organization should be consistent with this role and with maximizing the effectiveness of high-caliber technical personnel in performing technical work.

The proposed Agreement for Cooperation with Euratom, in addition to providing for a joint program to construct in the Euratom countries nuclear powerplants of proven types having a total installed capacity of approximately 1 million electrical kilowatts, provides for a joint research and development program centered on the reactors involved. Proven types are presently considered to be pressurized-water, boiling-water, and organic-moderated reactors. The research and development program will be aimed primarily at the improvement

of the performance of the reactors and at lowering fuel-cycle costs and will also deal with plutonium recycling and other problems relevant to the reactors. The research and development program will be established for a 10-year period, with the United States and Euratom each contributing about $50 million during the first 5 years. The Committee believes that this program will result in substantial advances in reactor technology, will provide an important precedent for international cooperation, and deserves full support.

7. RECOMMENDATIONS FOR THE TECHNICAL PROGRAM IN THE NEAR FUTURE

Our conclusions are that the technology of nuclear power is well advanced in this country, that it still has a long way to go before it can be turned over entirely to private industry, and that if the AEC leads a vigorous development program there is a fair chance that nuclear power may be competitive with power from fossil fuels in some parts of this country within 10 years and in most of the country within 20 or 30 years.

We have reviewed the present status of the technical program and find it generally sound. To strengthen it and give it guidance, particularly in the immediate future, we have made a number of recommendations, some general and some detailed, as follows:

(1) A broad program of general applied research should be generously supported by a substantial increase over the level of the fiscal year 1959 expenditures for this category of work. In addition, some of the work now being done under specific reactor projects should be transferred to this program.

(2) Within the program of general applied research, increased effort should be put on the fuel cycle, including fuel-element fabrication.

(3) Within the program of general applied research, increased effort should be put on reactor physics, including the determination of eta for U^{233} and other similar constants.

(4) Construction of further prototypes[5] of boiling-water reactors that advance the art should be encouraged. Studies being carried out by the Commission and by industry will probably indicate the desirability of constructing one or two of these prototype reactors starting in 1959. If further studies on pressurized-water reactors bring forth promising new ideas, prototype reactors of this kind should also be constructed.

(5) Work on nuclear superheat should be directed toward incorporation of this feature in a prototype reactor at an early date.

(6) Work on pressure tubes and pressure-tube reactors including that recently initiated is commended and should be continued, since this offers a possibility of unlimited reactor size and a promising method of achieving nuclear superheat.

(7) Since the concept of organic cooling looks attractive from the point of view of reducing capital costs, a further reactor experiment or prototype reactor should be started in 1959 if present design studies, particularly those on heavy-water moderated and organic-cooled reactors, come to promising conclusions.

(8) The general work on sodium as a coolant should be encouraged by continued operation of the sodium reactor experiment and by pushing the new development work on sodium systems. Construction of the Hallam plant is probably advisable but should be given a lower priority than the general work.

(9) The thorough investigation of a sodium-cooled and heavy-water-moderated reactor should be continued.

(10) Since there is a need for a flexible reactor test facility and for experience with a gas-cooled, civilian power reactor at an early date, a reactor similar to that designed by Kaiser Engineers and ACF Industries should be constructed starting in 1959. Flexibility should be introduced into the design to make the reactor suitable for testing fuel elements for gas-cooled reactors at temperatures up to 1,400° F.

(11) Research and development support should be continued for the gas-cooled, heavy-water, pressure-tube reactor proposed by the Florida West Coast-East Central Nuclear Groups.

(12) Subject to the present technical review by the AEC, the Commission should support the research and development required for the advanced gas-cooled reactor proposed by the Philadelphia Electric Co. Support should also be continued on the somewhat similar concept of the pebble-bed reactor.

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[5] Prototype is defined in this report as a pilot plant designed with the ultimate construction of a large plant in mind. See p. 29.

(13) The aqueous homogeneous, molten bismuth, and molten salt reactors all offer the possibility of reducing the cost of the fuel cycle, and the last two offer the possibility of high-temperature operation. These three concepts for power reactors should be critically compared and work concentrated on the concept that appears the most promising.

(14) Work on reactors involving the U^{233} breeding cycle should be reduced until it is clear that the value of eta is such as to make breeding feasible. Such breeding may require use of slurries, and work should continue on developing the technique of handling slurries.

(15) Work on plutonium as a fuel should be pushed and the necessary facilities for this work provided.

(16) Work on fast breeders should continue to receive vigorous support.

The above recommendations are concerned with technology. Our Committee was instructed also to consider more general aspects of the program. In the following sections we will consider more long-range problems and the methods by which the whole program can be implemented. The recommendations arising from that discussion are given in section 11.

8. LONG-RANGE PROGRAM

In the preceding parts of this report we have defined the objectives of a U.S. nuclear power program and identified the kinds of knowledge required to reach these objectives and the various lines of work to be pursued in seeking this knowledge. We have appraised the present status of the program, both in general terms and in terms of specific types of reactors, and have made a number of specific suggestions for the immediate future. We have not put forward a specific program of reactor construction to be carried out over a period of 8 or 10 years.

In the development of a new technology like that of nuclear power, different types of activity dominate at different times. The period following the establishment of the 5-year reactor program of 1954 and of the power demonstration program has been dominated by construction, much of which is still underway. The first fruits of this period, results from the EBR–I, SRE, EBWR, HRE–II, OMRE, and Shippingport are now coming in but are still very incomplete. The present time is primarily a period of reassessment, as is illustrated by the number of specific reactor studies underway and by the series of general program studies appearing during 1958. We think it particularly difficult so early in this present period of reassessment to lay down a long-range program of construction of reactors specified as to type, size, and timing. We might feel it necessary to do so were there not four such lists already available for comment. As it is, we do not wish to encourage a kind of Gallup poll as a method of determining a reactor program. Such lists are too likely to be quoted out of context and to impart a rigidity to the program which is neither intended nor desired.

These four lists, all appearing in 1958, have emanated from the Edison Electric Institute, the Atomic Energy Commission, the Joint Committee on Atomic Energy, and the General Electric Co., and are compared in the December issue of the "Forum Memo" published by the Atomic Industrial Forum. Although the General Electric report recognizes the desirability of developing other types of reactors, the list given is confined to boiling-water reactors and is therefore too limited to serve our purpose. There seems to be no serious inconsistencies among the other three lists if they are considered in the context of the assumptions and comments carried in the documents which present them. All are recognized as tentative and frequent reconsideration is urged in each document. In all three cases it is recognized that some of the suggested reactors will be eliminated from the program on the basis of further information.

By our terms of reference we are asked to include both the AEC statement and the JCAE staff memorandum in our considerations. The review of the technical program in sections 4, 5, 6, and 7 of our report was prepared deliberately without reference to these documents. The general similarity between the present document and those of the AEC and the JCAE staff arises, therefore, from the state of the technology. In the remainder of this report, as in sections 1 and 2, we shall make frequent reference to the AEC statement or to the JCAE memorandum. In general, we like them both and find them compatible with each other and with our own views. We shall identify specific areas in which we disagree with them.

We find the types of reactors listed as worthy of consideration in these two documents (and also in the EEI report) are generally consistent with our own views. Since the JCAE memorandum is somewhat more specific for the long range, since it contains cost estimates, and since comments on it from many sources are available to us, we will refer principally to it in the remainder of this section and the following sections.

As to the technical program in the JCAE memorandum, we differ from it in two respects. We would put greater emphasis on breeding and greater emphasis on prototype plants compared to large-scale plants. We believe that the information obtainable from so-called second- or third-generation powerplants of some 200-electrical megawatt capacity can be obtained more quickly and more cheaply from second- or third-generation prototype plants of capacity up to about 80 electrical megawatts. We think the need for demonstrating the feasibility of large-scale nuclear powerplants has passed and such plants should be built only when their costs are low enough to be acceptable to utilities. If such a stage were reached soon enough to meet the time schedule set by the JCAE report for 200-electrical-megawatt plants, we would be pleased, though surprised in some cases. It should be understood that such a stage has arrived or is near at hand in Western Europe, a fact that reduces still further the need of large plants in this country. We shall return to this question of large-scale plants in our discussion of administrative implementation (sec. 10, below).

The JCAE program envisaged the construction of approximately a million kilowatts capacity of nuclear power in the next 7 years or so. Our proposed emphasis on prototypes would reduce this to perhaps as low as 500,000 kilowatts. Additional capacity may be financed and built by utilities before the end of that period, thereby increasing the total capacity. Our committee would welcome such construction.

9. COST ESTIMATES FOR THE PROGRAM

The JCAE staff memorandum estimates a total cost, exclusive of laboratory support facilities, for its proposed program of $250 to $275 million a year. About half of this would be for general reactor research and development and the other half for design and construction of specific reactors. These estimates are based on the assumption that a total capacity of about 1 million electrical kilowatts would be built in 7 years. Design costs are included for those reactors actually built and also for those dropped at a late stage on the basis of detailed assessment of cost and value. It must be emphasized that this is total cost, not Government cost.

If prototypes of average size of 50 electrical-megawatts are substituted for the 200 electrical-megawatt plants in the JCAE program, the estimated total cost might be reduced by about $50 million a year and then become $200 to $225 million a year. How much of this would have to be carried by the Federal Government it is impossible to say. Private industry might make a considerable contribution to the costs of construction of prototype plants, but probably most of the design studies for systems not built and most of the research and development would have to be paid for by the Federal Government. Between $150 and $200 million a year is the best guess we can make for the cost to the Federal Government. This does not include the costs of laboratory support facilities or of the Euratom program. Since the corresponding AEC expenditures for the current fiscal year are estimated to be about $190 million, we believe the proposals in the JCAE memorandum and the present report should be called revised programs, not expanded programs, from the national standpoint.

10. IMPLEMENTATION OF THE PROGRAM

The type of program we have outlined seems to us consistent with the present state of the technology and with the probable attainment of the stated objectives. It might be speeded up somewhat by greater expenditure, but we doubt whether this is necessary for the immediate objectives and we believe it might be undesirable for the ultimate objective of really cheap nuclear power produced in plants built and operated by publicly and privately owned utilities in the accepted pattern of power production. Furthermore, we think a "crash" program might distort the technology and waste nuclear fuel.

It is not yet possible for the Federal Government to divest itself of the responsibility for the development of nuclear power technology. To attain the objectives we have stated, the Federal Government must exert positive leader-

ship. More specifically, the AEC must exert positive leadership and must be recognized as responsible for technical decisions. We approve the modification that the AEC has recently made in the power demonstration program as announced in the following statement:*

"In conformance with recently enacted legislation, the third invitation is further modified to provide that the Commission, prior to entering into any new agreements under the power demonstration reactor program, will make public announcements inviting proposals for reactors it considers technically desirable for construction. * * * Previously, under the terms of the third invitation, there was no limitation on the type or size of nuclear powerplants which might be proposed, except that they must give promise of making a significant contribution toward achievement of commercial nuclear power. Now, however, such proposals must be responsive to the type of project specified in the invitation."

Such a system should not discourage industrial initiative. It is always possible and desirable for industry to make suggestions which may lead to an invitation for a particular reactor system. In fact, the AEC later in the same announcement gives specific assurance on this point.

We find little to criticize in the general philosophy expressed in the concluding sections of the JCAF staff memorandum beginning with the section headed, "Organization and Administration of Program." We agree with the first sentence of that section which reads, "Since the U.S. Government considers the objectives of this program of great importance from a national and international standpoint, the Atomic Energy Commission must provide positive leadership to make certain the objectives are achieved in terms of practical results." We agree also with the first two sentences of the next section, which read: "Projects wholly financed by private enterprise should be encouraged to the fullest extent possible. It should be recognized, however, during this transition period probably not many such plants will be built."

We agree that the AEC should continue to be responsible "for the conduct of the base program of research and development through its national laboratories, industrial contractors, universities, and nonprofit institutions." We agree that the AEC should assume "positive direction of the reactor development program from the stage of feasibility studies of promising reactor concepts, through the necessary reactor experiments, up through the construction and operation of experimental prototype reactors." We share the hope implied later in the JCAE memorandum that at least some prototypes will be wholly or partly financed by industry. If the AEC contributes a significant part of the cost of such prototypes, the AEC should have sufficient control of their operation to insure that they produce the maximum of information. That is their principal purpose.

As stated in section 8, above, the Committee here reporting does not agree with the JCAE staff recommendation on large-scale plants. Even here we believe our disagreement is not as basic as it might at first appear. We can probably express our point of view best by an example. If the AEC decided 2 years from now that a large-scale plant of a certain type should be built, announcement to that effect would be made and proposals solicited as outlined in the JCAE staff memorandum. According to the JCAE memorandum, if no satisfactory proposals were made for construction financed by a public or private utility "the Commission would undertake responsibility for the completion of design and construction of the project if it were still deemed desirable." The attitude of our Committee would be that the abence of a proposal was prima facie evidence that the time had not yet come to build a large-scale plant of the particular type proposed and that the invitation had better be reshaped, possibly to call for a smaller prototype, or be withdrawn.

For prototype plants we accept the possibility of AEC construction and ownership but, when possible, prefer private financing and ownership with whatever degree of assistance may be necessary, provided that the AEC retains sufficient control to operate or change the plants in order to obtain technical information.

As to the various forms of financial assistance now permitted and enumerated in the JCAE memorandum, we think they should be recognized as expenditures by the Government for the purpose of developing technology. Nor do we have any objection to a capital grant such as has been proposed at various times if a form of grant can be devised which encourages economy and efficiency. Such

* AEC Press Release A–305 of Nov. 17, 1958.

a scheme should also minimize distortion of technology. Conceivably a combination of capital grant and low charge for fuel could be worked out which would distort the technology less than either by itself. Assistance on research and development should be just that and not extend into core or fuel-element fabrication.

We have expressed opposition in general to construction subsidies for additional large-scale nuclear powerplants, and we are skeptical of the need for such plants before costs are substantially reduced. However, we do not wish to preclude Government assistance if the major portion of the construction is financed by utilities and if a net saving in over-all effort can be accomplished thereby. We hope that even prototype reactors can be built with a minimum of assistance, but we are prepared to accept Government funding and ownership if need be.

We have nothing to add to the suggestions put forward in the JCAE staff memorandum for assistance on foreign programs. We have not examined the Euratom arrangements in detail, but we would like to express general approval of the actions in this area by both the executive and legislative branches of the Government. We also approve continued cooperation with and support of the International Atomic Energy Agency and other international programs. Reactor development will be accelerated as various groups try different approaches under different economic conditions and fully exchange the information that results.

Many technical obstacles must be overcome before nuclear power can be competitive with power from fossil fuels and its further development carried forward in our normal pattern of technical progress. Success in the period of transistion that lies before us requires the wholehearted cooperation of the AEC, the JCAE, and industry. We believe that the general formulation of policy is properly the joint responsibility of the AEC and the JCAE. Approval of the policies and programs adopted inevitably involves actions by other parts of both the executive and legislative branches of the Government. No program will be successful it it is unacceptable to the industries which must carry out a large part of the work; therefore, the views of representatives of industry should be taken into account. We do not pretend that such extensive cooperation will be easy nor expect that everything proposed will be unanimously accepted. Yet we believe that all the groups involved are more nearly in accord than at any time in the past several years and that the time it ripe for an agreement on objectives, on the general technical features of a program, and on the methods of implementing it.

In general, we feel that the necessary technical program can be carried forward most rapidly by giving the AEC the maximum of authority and responsibility. The AEC should have the power and responsibility for technical decisions and the greatest possible flexibility in carrying them out at reasonable cost to the Government. With the acceptance of this responsibility by the AEC, the JCAE can confine itself to review, criticism, and suggestion of the kind that has so often proved useful. Members of both groups have difficult roles to fill, but we see no basic differences in their objectives. Cooperation between the two groups is the most important single factor in the success of this country's nuclear power program.

11. GENERAL RECOMMENDATIONS

We believe the three objectives set forth in the AEC statement of June 3, 1958, and the JCAE memorandum of August 1958 are sufficiently consistent and clear to form the basis for a national nuclear power program. We have added two other objectives (sec. 2) already implicit in these documents. We believe all these objects are probably attainable and are of great importance to this country. To attain them will require a vigorous and well coordinated effort by government and industry.

We wish to conclude this report by adding to the list of technical recommendations given in section 7 some recommendations of a broader character. These are as follows:

1. To promote better understanding of the U.S. nuclear power program, both in this country and abroad, the Atomic Energy Commission and the Joint Committee on Atomic Energy of the Congress should issue a formal statement of objectives, along the lines of those listed in section 2 of this report.

2. This statement should explain the necessity for leadership by the Federal Government, in cooperation with industry, and describe how this leadership is to be exercised.

3. Possible methods of Government assistance in implementing the program should be examined with a view to maximum flexibility and minimum distortion of the technology.

4. The United States should continue cooperation with and support of the International Atomic Energy Agency, Euratom, and other international programs, recognizing the fact that reactor development will proceed much more rapidly if different approaches are tried by different groups under different economic conditions but with full exchange of information.

5. The technical program should give special emphasis to such factors as neutron economy in order to promote the most efficient use of fissionable and fertile materials.

6. Prototype [7] reactors should be emphasized rather than large power reactors until the latter can be wholly or nearly self-supporting.

7. Ad hoc committees such as the one here reporting should be appointed from time to time to review the program.

Finally, we would like to thank the staff of the AEC in general, and Dr. Pittman, Mr. Staebler, and Dr. Fine (executive secretary of the Committee), in particular, for their assistance. We are indebted to the Joint Committee on Atomic Energy for making available to us the comments that have been received on the JCAE staff memorandum of August 1958. We are also grateful to various witnesses from Government, industry, and universities for coming to Washington, often at short notice, to help us.

Respectfully submitted.

J. B. BLACK
M. W. BOYER
H. BROOKS
E. V. MURPHREE
E. C. STARR
R. E. WILSON
H. D. SMYTH, *Vice Chairman.*
A. TAMMARO, *Chairman.*

APPENDIX A

ANNOUNCEMENT OF APPOINTMENT OF AD HOC ADVISORY COMMITTEE ON REACTOR POLICIES AND PROGRAMS, U.S. ATOMIC ENERGY COMMISSION, WASHINGTON, D.C.

No. A–265

[For immediate release Wednesday, October 8, 1958]

CHAIRMAN M'CONE APPOINTS REACTOR ADVISORY COMMITTEE

Chairman John A. McCone of the Atomic Energy Commission has appointed an Ad Hoc Advisory Committee on Reactor Policies and Programs. The Committee held its first meeting last week. The Chairman attended the meeting and expressed the Commission's thanks to its members for their public service in accepting membership on it.

The members of the Committee are Mr. James Black, chairman, Pacific Gas & Electric Co.; Mr. Marion W. Boyer of the Standard Oil Co. of New Jersey and formerly General Manager of the Atomic Energy Commission; Dr. Harvey Brooks, dean of engineering and applied physics, Harvard University, and presently a member of the Commission's statutory Advisory Committee on Reactor Safeguards; Mr. Eger V. Murphree, president, Esso Research & Engineering Co. and presently a member of the Commission's statutory General Advisory Committee; Dr. Henry D. Smyth, chairman, Board of Scientific and Engineering Research, Princeton University, and formerly a Commissioner of the Atomic Energy Commission; Mr. Eugene Starr of the Bonneville Power Administration; Dr. Robert E. Wilson, formerly chairman of the board of Standard Oil Co. of Indiana, presently a member of the Commission's statutory General Advisory Committee. The Chairman of the Committee, under the Code of Federal Regu-

[7] Prototype is defined in this report as a pilot plant designed with the ultimate construction of a large plant in mind. See p. 522.

lations stipulating how boards and committees advisory to the Commission shall operate, is Mr. A. Tammaro, Assistant General Manager for Research and Industrial Development. The Committee elected Mr. Henry D. Smyth as its Vice Chairman.

The Committee was appointed for the purpose of reviewing the Commission's civilian power program and advising the Commission in connection with its future power reactor policies. The appointment of such a committee is in accord with the recommendations of the Joint Committee on Atomic Energy of Congress and the General Advisory Committee to the Atomic Energy Commission.

Appendix B

Terms of Reference of Ad Hoc Advisory Committee on Reactor Policies and Programs

It shall be the purpose of the Ad Hoc Advisory Committee on Reactor Policies and Programs to—

(1) review the Commission's civilian power program;

(2) advise the Commission in connection with the formulation of a sound basic policy in the light of our current economy and the present stage of development of nuclear power technology;

(3) assist the Commission in establishing new goals and redefining the problems connected with the foreseeable expansion of commercial utilization of nuclear power and the concomitant development of a vigorous nuclear equipment manufacturing industry; and

(4) recommend immediate and long-range programs to achieve the Commission's new goals.

In advising the Commission on these matters, the Committee shall take into consideration all relevant economic, political, and international aspects, as well as the predominant technical factors involved in a viable nuclear power program based on U.S. national interests. The Committee shall give specific attention to the long-range program outlined by the Commission at the 1958 "202 Hearings" before the Joint Committee on Atomic Energy and to the document entitled, "Proposed Expanded Civilian Nuclear Power Program," dated August 1958, prepared by the JCAE staff.

The Committee shall also carefully review the various reactor concepts now under study by the Commission and shall make positive recommendations on the basis of comparable promise as to which, if any, of these concepts should have greater or lesser emphasis placed on them, or should be eliminated from the Commission's program. It shall, in addition, make recommendations with respect to new concepts which should be added to the Commission's program and the level of effort which should be placed thereon.

The Committee will develop an agenda and establish a schedule of meetings under which a final report can be submitted to the Commission no later than December 1, 1958.[1]

In keeping with the requirements of the Code of Federal Regulations (sec. 7.4 of 10 CFR, pt. 7), which sets forth regulations under which advisory boards to the Commission shall operate, Mr. A. Tammaro, Assistant General Manager for Research and Industrial Development, has been appointed as Chairman of the Committee.

Appendix C

List of Briefings of Ad Hoc Advisory Committee on Reactor Policies and Programs

October 3: Briefing on the AEC civilian power reactor program by Messrs. Pittman and Staebler of the AEC Division of Reactor Development.

Briefing on the program for nuclear propulsion of merchant ships by Mr. Godwin of the AEC Division of Reactor Development.

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[1] Note by the Chairman of the Committee: This date had to be extended by a month in order to schedule the necessary number of meetings and to accord with other commitments by the members of the Committee.

October 27: Briefing on the availability of enriched uranium and heavy water and the components of cost of nuclear power by Mr. Fine of the AEC Office of Operations Analysis and Forecasting.

Briefing on the operating experience with the production reactors and the effect of volume on the cost of fabricating and reprocessing fuel elements by Mr. Quinn of the AEC Division of Production.

October 28: Briefings on the reactor and fuel-cycle programs of the Argonne National Laboratory by Messrs. Hilberry, Spinrad, Lawroski, and Foote of the Laboratory.

Briefings on the reactor and fuel-cycle programs of the Oak Ridge National Laboratory by Messrs. Weinberg, Lane, Briggs, and McPherson of the Laboratory.

November 6: Briefing on the plutonium recycle program by Messrs. Fryar and McEwen of the Hanford atomic products operation.

Briefing on boiling-water reactors by Messrs. Cohen, Maider, and Freeman of the General Electric Co.

Briefing on heavy-water reactors by Messrs. Worthington and Menegus of the Du Pont Co.

Briefing on pressurized-water reactors by Messrs. Weaver, Simpson, Krasic, Wells, and Jones of the Westinghouse Electric Corp.

Briefing on organic-moderated and sodium graphite reactors by Messrs. Starr, Siegel, Pearlman, and Trilling of Atomics International.

November 7: Briefing on liquid-metal-fuel reactors by Messrs. Haworth, Williams, Gurinsky, and Miles of the Brookhaven National Laboratory and Messrs. Landis, Schomer, Thomas, and Poor of the Babcock & Wilcox Co.

Briefing on the Shippingport reactor by Admiral Rickover, Commander Barnes, Mr. Mandil, and Mr. Rockwell of the AEC Division of Reactor Development.

Briefing on the utilization of uranium and thorium resources by Mr. Stewart of the AEC Division of Reactor Development.

November 28: Briefing on the relationships of the U.S. atomic energy program to U.S. foreign policy by Messrs. Farley and Schaetzel of the Department of State.

Discussions of the U.S. nuclear power program with Mr. Zinn of the General Nuclear Engineering Corp. and Mr. Benedict of the Massachusetts Institute of Technology.

Briefing on gas-cooled reactors by Mr. Atwood of the AEC Division of Reactor Development and Mr. Charpie of the Oak Ridge National Laboratory.

In addition to these briefings, written material was prepared for the ad hoc advisory committee by the AEC Divisions of Reactor Development, Production, and Raw Materials and the Office of Operations Analysis and Forecasting. Reports and letters were sent for the information of the Committee by the Oak Ridge National Laboratory, the Brookhaven National Laboratory, the Babcock & Wilcox Co., Hanford atomic products operation, and American-Standard. Other reports were provided to the Committee by the AEC staff.

Appendix D

List of Reactor Design Studies Being Sponsored by the AEC

The AEC has recently contracted for preliminary design and engineering studies and cost estimates, to be completed in the spring of 1959, on advanced designs of nuclear powerplants employing the following reactor types:

Pressurized-water reactors by the Stone & Webster Engineering Corp., associated with Combustion Engineering, Inc.

Boiling-water reactors by Ebasco Services, Inc., associated with the General Electric Co.

Organic-cooled reactors by the Bechtel Corp., associated with Atomics International.

Heavy-water, natural uranium reactors by Sargent & Lundy, associated with Nuclear Development Corp. of America.

The AEC has also approved, as a basis for contract negotiation, the design-study phase of a proposal from the Puerto Rico Water Resources Authority for a boiling-water nuclear powerplant incorporating nuclear superheat.

Other studies deal with new reactor concepts, such as the following:

Water-cooled, fluidized-bed reactor by the Glenn L. Martin Co.

Organic-cooled, fluidized-bed reactor by the Westinghouse Electric Corp.

Gas-cooled, pebble-bed reactor by Sanderson & Porter.

Sodium-cooled, modular-core reactor by the General Electric Co.
Sodium-cooled, calendria-design reactor by Atomics International.
Mercury-cooled fast reactor by American-Standard.
Coupled fast-thermal reactor by the Argonne National Laboratory.

In addition, where reactor concepts appear to have promise, design studies are carried out by the AEC on possible reactor experiments for further exploration of those concepts.

APPENDIX 3

THE OUTLOOK FOR THE U.S. ATOMIC ENERGY PROGRAM

(By Senator Clinton P. Anderson, Chairman, Joint Committee on Atomic Energy, Washington, D.C.)

[Nucleonics, March 1959]

The editor of Nucleonics asked me to put on paper my hopes and expectations as to activities of the Joint Committee on Atomic Energy in the 86th Congress.

I am as agreeable to his suggestion as he was cordial in his invitation. I shall try to cover the civilian atomic power program and related subjects, as well as my views on taking a long look at the future. I would emphasize that at this stage I am only speaking for myself, but expect to discuss many of these ideas with my associates before this article sees the light of day.

Before I launch off into the next few years, a few backward looks may be appropriate. In a sense I could almost have said when I assumed the chairmanship on January 30, 1959: "Isn't this about where I left off in 1956?" In some ways this would have been true. For in 1955, I instituted a study by the McKinney Panel of where we stood and where we had to go in civilian atomic power; and in 1956 my colleagues and I, with some good staff assistance, tried to give the lagging atomic power program a shot in the arm. We almost made it with the committee's version of the Gore-Holifield bill which cleared the Senate but was defeated by a close vote in the House. Atomic power would be much farther ahead if it had passed.

But the committee's bill wasn't passed. However, in all truth, we made considerable progress during the next 2 years under Carl Durham's enlightened chairmanship. Thus we enacted most of Carl's six-point program,[1] including authorization of the Hanford convertible reactor, increased reactor research and development funds, and passage of the Price-Anderson indemnity law and the Euratom Cooperation Act of 1958. We also authorized a number of reactor design studies, and pushed the Atomic Energy Commission into a major effort in gas-cooled reactor technology.

A major milestone in 1958 was the issuance of the Joint Committee's staff report in August 1958 which Chairman Durham and I strongly endorsed. This report was the culmination of a long series of reviews on the atomic power program, beginning with the McKinney report in January 1956, the Joint Committee on Atomic Energy acceleration report in July 1956, the American Assembly and National Planning Association reports in 1957, the Joint Committee and AEC seminars in the winter of 1957, the Edison Electric Institute report of March and July 1958, and the Atomic Energy Commission statement of June 1958.

Now in 1959 we have received the AEC ad hoc committee report, have held extensive informal seminars with all segments of the atomic industry, and heard AEC Chairman McCone in executive session. By the time this article is published we will have completed part of our statutory "202" hearings and learned more about AEC plans for the atomic power program, particularly the gas-cooled reactor problem.

In short, I think this program has had sufficient review. Like the reactor experts and others in our seminars in early January, I am of the opinion that what we need now is action. We have had enough words. The question is: What should we do?

WHAT SHOULD WE DO?

1. First off, I would say that we should agree on a set of objectives. This should not be difficult, since the objectives of AEC and its ad hoc committee and

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[1] In a speech at the Nuclear Congress in Philadelphia in March 1957, Chairman Durham specified a six-point program.

the Joint Committee on Atomic Energy staff report are very similar. Thus I would be willing to buy those objectives of the AEC ad hoc committee which are the most inclusive. These are as follows:

"(*a*) Fortify the position of leadership of the United States in the technology of nuclear power for civilian use.

"(*b*) Reduce the cost of nuclear power in this country to a point competitive with power from fossil fuel at least in some areas within 10 years.

"(*c*) Reduce the cost of nuclear power to the competitive point in friendly foreign nations having high costs for energy in less than 10 years through a comprehensive program of assistance clearly defined and vigorously pursued.

"(*d*) Achieve a substantial reduction in the cost of nuclear power over the next 20 or 30 years by continuing studies which may ultimately lead to great cost reductions, but which are unlikely to bear fruit in the next 10 years.

"(*e*) Make the fullest use possible of the nuclear energy latent in both uranium and thorium, especially by breeding, recognizing that U^{235} alone is probably not sufficiently plentiful to contribute significantly to our power needs over the long range."

2. Next I believe we should agree as to methods. This is admittedly a bit more difficult, but I hope AEC will buy its ad hoc committee's recommendation which in turn supported the JCAE staff report in these words:

"We find little to criticize in the general philosophy expressed in the concluding sections of the JCAE staff memorandum beginning with the section headed, 'Organization and Administration of Program * * *.'

"We agree that the AEC should continue to be responsible 'for the conduct of the base program of research and development through its national laboratories, industrial contractors, universities, and nonprofit institutions.' We agree that the AEC should assume 'positive direction of the reactor development program from the stage of feasibility studies of promising reactor concepts, through the necessary reactor experiments, up through the construction and operation of experimental prototype reactors.' We share the hope implied later in the JCAE memorandum that at least some prototypes will be wholly or partly financed by industry. If the AEC contributes a significant part of the cost of such prototypes the AEC should have sufficient control of their operation to insure that they produce the maximum of information. That is their principal purpose."

If we get this policy on AEC development and construction of some experimental prototypes adopted, we should have smoother sailing on second- and third-generation prototypes and full-scale plants. In my opinion we should begin a program of Government grants to private utilities covering a good part (75 to 90 percent) of the differential between the estimated cost of a nuclear plant and a conventional plant. We should also have a parallel program of assistance to cooperatives and public power organizations (local, State and Federal) along the lines of the second-round power demonstration program.

3. After we agree as to methods, we must begin to get more concrete as to the level of financial assistance and effort required by AEC and industry over the next 5 to 10 years.

The funding situation for the AEC civilian atomic power program is a very complex business. The funding for the additional general research and development required, plus the research and development and capital expenses for particular reactor projects, will undoubtedly add up to considerable sums of money.

The Joint Committee staff report estimated a total additional cost of $875 million for the expanded program over a 5- to 7-year period, or an average of about $125 million additional capital and operating costs over a 7-year period. This would include AEC and private costs.

The AEC ad hoc committee, using smaller prototypes, indicated the Joint Committee staff estimate could be lowered $50 million per year. This would amount to an average of $75 million per year of additional costs. There is some doubt whether the staff report and ad hoc figures are comparable when added to alleged "base" program figures and compared with current expenditures.

In any event the additional funds required to expand or accelerate the program are quite modest in comparison with military expenditures, or, as Commissioner Floberg has pointed out, in relation to capital expenditures for conventional electric power facilities. To repeat, if we can get a new energy resource and enhance our world technological leadership for less than 1 percent of total annual national product, we are doing mighty well.

4. More specifically we have to agree, or agree to disagree, on what we need to authorize for the next year or two, particularly fiscal year 1960. No author-

ization comes out of the blue, and we must, of course, look at the projects under design or consideration by the Atomic Energy Commission. The AEC has design studies underway on the following types of reactors, as authorized by the Joint Committee: heavy water-natural uranium, boiling water, pressurized water, organic moderated, and a reactor using nuclear superheat. The AEC also had under consideration a prototype of a homogeneous slurry type.

Depending on how these studies turn out, it would appear appropriate that we authorize a program on these lines:

1. AEC construction of one or two experimental prototypes at AEC sites with the power absorbed at the site.
2. AEC support of one or two large-scale or intermediate-size second- or third-generation plants under the power demonstration program utilizing the differential construction grant on a trial basis.
3. AEC support of extension of second-round power demonstration program for one or two small- or intermediate-size second- or third-generation plants.
4. Authorization of several additional design studies of promising types.

It is at this point that we may run into trouble with the Bureau of the Budget, although I hope that Chairman McCone will be able to get backing for this program.

I have been asked several times whether I would support the rumored cutback of AEC effort on certain reactor types. My position has been that I would be willing to see a reasonable cutback of effort if the savings can be used to accelerate the reactor program along the lines I have indicated. Undoubtedly there are activities which should be deemphasized, but I do not subscribe to an abandonment of our diversified program.

On the question whether we should adopt the ad hoc committee suggestion that we confine our efforts to prototypes of 80 electrical megawatts or under, I believe it is not possible to generalize that broadly. Our informal seminars with industry in January confirmed my view that in some cases we may have to go to larger sizes to prove out or demonstrate a reactor type from a technical or economic standpoint.

NUCLEAR MARITIME PROPULSION

When I was chairman of the committee in 1956, I suggested the construction of a nuclear-propelled oil tanker. During the hearings before Senator Magnuson's committee, I testified that this would be a better alternative, in my opinion, than the cargo-passenger ship which is now being constructed as the NS *Savannah*. Again last year, I had ready an amendment to the authorization bill to provide $7 million (opposed by the Budget Bureau) for construction of a nuclear reactor for the T–5 oil tanker. However, because of floor debate over other portions of the authorization bill, I reluctantly decided to withhold my amendment. Instead I inserted in the Congressional Record a statement of my views supporting the construction of a nuclear-propelled oil tanker as soon as possible. I hope that the Commission, or the Bureau of the Budget, will not delay this longer but instead will request funds for a nuclear-propelled oil tanker this year.

PLUTONIUM PROGRAM

As for the plutonium program, the Joint Committee has attempted for many years, with only partial success, to disentangle the peculiar arrangement between the Commission and the Department of Defense whereby Defense only requests as much plutonium as the Commission plans to make. Defense has not based its requests upon long-term national defense needs and a realistic small-weapons program.

Last year the Congress authorized construction of a convertible-type production reactor at Hanford. I believe the Joint Committee and the Congress will continue to advocate an assured plutonium supply as necessary to protect our national defense program. We have recently learned that the Defense Department has finally developed a long-term requirement for its future needs for plutonium. But no one should be surprised if this long-term requirement coincides with the production from current AEC facilities plus improvements and the new Hanford reactor. So, round and round they go.

With regard to buyback prices to be paid to domestic atomic powerplants for their byproduct plutonium, I believe the Commission should come up with recommendations resulting from a series of discussions with the Joint Committee

staff as contained in an exchange of correspondence dated June 3 and July 9, 1958.[2] This would provide an interim price for unrestricted use between the present $30 price [the weapons value] which prevails until 1963, and 1968 or so when the price should get down to the fuel value, $12 per gram. This interim price should be set in such a way as not to distort civilian reactor technology by emphasizing plutonium production.

EURATOM

The proposed Agreement for Cooperation with Euratom was considered by the Subcommittee on Agreements for Cooperation of the Joint Committee on January 21 and 22, 1959. The joint program appears to be making headway in terms of getting necessary criteria and invitations for proposals established, negotiating the basis for a loan from the Export-Import Bank, and proposing an insurance and indemnity program to cover third-party liability.

I am somewhat uneasy whether the time schedule of December 31, 1963, may be too optimistic, especially in view of the growing stocks of coal in Europe. I hope that the parties to the joint program will seriously consider the advantages of flexibility regarding the time scale up to December 31, 1965, on two reactors.

I was also concerned about the problem of "bailouts" of existing projects. On this point I was assured that the established criteria, including competitive bidding, would apply to these projects across the board. It was also explained that the Euratom subsidy provisions could not be used to relieve a utility or supplier of an obligation already assumed. This still doesn't take care of the question whether we realized that we apparently were not authorizing a million kilowatts of new capacity, as we thought, but were taking over projects developed under different circumstances. In any event, the committee will scrutinize the projects carefully when they are submitted for authoriaztion.

INTERNATIONAL ATOMIC ENERGY AGENCY

We need to find something constructive and useful to suggest as a program for the International Atomic Energy Agency. Our good friend and former colleague, Sterling Cole, is now doing his best to instill life into the Agency. He has suggested in a speech before the Atomic Industrial Forum that unless the United States, the United Kingdom, and the U.S.S.R. cease and desist their bilateral atomic energy programs, the Agency might just as well go out of business.

My guess is that the reason for a slump in the popularity of IAEA is the fact that our friends in Europe prefer to deal directly with us under bilaterals than through some international agency where Russia looks at every deal and can inspect every development.

Perhaps everyone has expected too much of the International Atomic Energy Agency. Certainly, the idea of its being the world's only broker and policeman for distribution of atomic materials is not working out.

Maybe we should lower our sights, and focus on some of the things that we realists thought the Agency might be able to do; namely, to serve as a kind of middleman between the Western allies, the neutral countries, and the Iron Curtain bloc. It had been my thought that the Agency could develop a modest but positive role in promoting the peacetime atom, particularly in the neutral and underdeveloped countries.

Thus IAEA could sponsor the development of standards and codes for reactor safety and insurance and indemnity, following the example set in its work on radiation protection. In the field of waste disposal, IAEA could develop international standards, and perhaps sponsor or participate in an international research and development effort to control safe handling and disposal of radioactive wastes.

Once it has become a little better established, the International Atomic Energy Agency should consider a modest program for sponsoring or participating in atomic power development in underdeveloped areas, such as Asia.

I have been recently informed that IAEA has begun a more ambitious survey on indemnity problems, and initiated further studies in atomic power development. This is all to the good. But sometime in the not too distant future it will have to go beyond the study stage.

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[2] See pp. 433–435 of hearings on AEC authorizing legislation, May–June 1958.

URANIUM PRODUCTION

Another group kept waiting in the wings while our atomic power program languishes is, of course, the uranium producers. Jesse Johnson and the Division of Raw Materials of the Commission have always done an outstanding job in supplying the needs of our atomic program. For the last year or two they have, understandably, had to start putting on the brakes on our uranium production because the power program has not yet generated a large market for uranium.

Now there is talk of stretchouts and further cutbacks in the uranium program. All this may not be necessary, however, if we agree to accumulate a small working inventory or uranium concentrates until such time as we can get the atomic power program going.

PATENTS

On patents: The Joint Committee staff is studying this question, and it is still too early to make many comments in advance of the public hearings next April. However, I am inclined to think there are some pretty good policy reasons for extending the so-called reserve power of the compulsory licensing provisions beyond the September 1, 1959, date when they are now due to expire. Occasionally there arises some sound and fury about AEC contractor patent problems, but I believe that most people in the industry recognize that contractors are entitled to either patents or Government money, but not both at the same time.

REACTOR SITE SELECTION CRITERIA

I believe we are about at the stage where the Congress should consider whether to require the AEC to establish (by means of a regulation) criteria for the selection of sites for atomic powerplants. Along with the criteria might be a requirement that applicants for a construction permit must submit alternative site proposals, with a further proviso that no permit should initially be issued for a site tentatively disapproved by the Advisory Committee on Reactor Safeguards. I am still of the opinion that it is absurd to permit tens of millions of dollars to be invested in an atomic powerplant at a site when there is substantial doubt among experts whether the plant will be safe at that location.

GUIDING PRINCIPLES

So much for my views on a number of programs and problems which the committee will review in the next 2 years. On several occasions I have pointed out that we have the opportunity to begin a new era in the relationship of Government and industry in atomic energy development. In going into this new era, I believe we should keep three principles or maxims in mind:

1. *Good faith.*—Several of us on the Joint Committee have felt there was a certain lack in this regard in the executive branch and certain private organizations in past years. On a number of occasions the private utilities appear to have been using delaying tactics or acting as the "reluctant dragon" in taking action only when necessary to forestall Government construction. In its December issue Nucleonics pointed out that a major motivation of the 50 utilities in the Philadelphia Electric-General Dynamics gas-cooled proposal was political—to stave off Government construction of the experimental prototype. In its February editorial, Nucleonics refined this word to the term "ideological."

I have tried to bury the phony public power issue many times, only to have it arise again. I am happy that Mr. McCone agrees with me that it is a false issue. But I repeat that the lack of good faith in raising this issue is giving private industry a black eye, and will continue to delay and confuse the program.

2. *No bailouts.*—I ran into this problem in connection with the foreign atomic power program, and particularly Euratom. One European utility in particular was extremely active and baldly stated it needed additional subsidy, whether it be in the plutonium buyback, or what have you. I am satisfied that this problem is being taken care of in Euratom. This no-bailout principle may have application domestically as well as in the foreign program.

3. *No conflicts of interest—legal or moral.*—It is inevitable, and even desirable, that there be a movement of personnel from AEC to private industry in the atomic power development field. But in the last year or two this movement among AEC top personnel has been precipitate. So much that, even though

Congress raised salaries appreciably, Chairman McCone has appealed to the committee to suggest means of recruiting and keeping key personnel.

There are certain laws affecting people who leave the Government—that they can't prosecute claims, etc.—and there are rules of good conduct or ethics. Thus, many conscientious former Government employees assiduously avoid any contact with their former associates, and work in fields unrelated to their former work for 2 years.

There is a good deal of sense to some sort of a cooling-off period. This would permit immediate past loyalties and debts (and sometimes even animosities) to subside before getting back into the whirl. Shouldn't AEC consider amending its rules of employee behavior to cover this?

Perhaps with such a cooling-off period really in effect, industry and AEC employees could more rationally consider the employee's real longtime worth and not his contact value. Maybe the turnover wouldn't be so great thereafter.

Ironically, AEC refuses to obtain the official and open advice of industrial contractor representatives on advisory panels because of the alleged conflict-of-interest problem, but seemingly permits its former top personnel to make unpublicized contacts with former associates and subordinates on proposed contracts and projects in which their companies have an interest.

NEED FOR LONG-RANGE PLANNING

I have felt for some time that the Congress, the executive branch, and the public are in need of some perspective and considered judgment on the very long-range requirements and demands for atomic power in its various advanced applications for the period 1970–2000.

My reasons as to the importance of such a project are twofold. First, it has been predicted that during this period the real domestic economic necessity for atomic power as a supplement to conventional fuels will probably take place. We need to reexamine the basis for these predictions to see if they are still valid, and to consider our uranium and thorium resources situation in connection with such predicted demands.

Second, and possibly more important, is our need to accelerate our technological effort as a part of our effort to maintain world leadership, particularly in view of the Soviet and Chinese threat. In addition to the need for our own economic advancement, we simply cannot afford to become a second-rate power in comparison with the rising military, technical, and economic might of the Soviet bloc. The Soviet successes with missiles and the sputniks, their growing atomic weapons stockpile, their excellent work in high-energy physics with advanced accelerators, and their accelerated civilian atomic power program, all attest to their growing military and technological strength and prestige. The November 1958 and January 1959 announcements of their 7- and 15-year plans adds another dimension to the threat in the form of economic warfare.

The primary aim of the Joint Committee's proposed short-term atomic power program is to help meet this immediate Communist threat to our technological supremacy; and our efforts in the foreign atomic power field should in part meet Soviet economic penetration and competition via the atomic powerplant route.

But the problem of how we go about meeting the longer range Soviet technological threat has been largely neglected in our current planning. As discussed earlier, we have reviewed and rereviewed our policies on atomic power over the next 5 to 10 years or so. But, apart from the earlier McKinney Panel report, we have not taken the longer view except with regard to specific projects.

Stating my proposal positively: We must assure the superiority of the scientific and technological capacity of the United States over the long pull, and demonstrate the virility of these programs under conditions of freedom. At the same time, we must find the political and administrative devices for making this technical know-how available in this country and abroad for material betterment.

It seems clear, then, that the Joint Committee should reexamine the programs under the jurisdiction of the Atomic Energy Commission and other interested agencies, to assess our technical progress and see what lies ahead. Perhaps we should appoint a panel of experts to do this. Or we might assign the survey to a subcommittee with expert consultants.

An important purpose of the survey would be to recommend objectives for long-range planning. In the past there has been too little of this. Instead, planning has often been narrowly limited to single programs. There have been too

many crash programs—too much hurry up and wait—too many single-purpose installations.

The Joint Committee needs to know what is new, and what promising roads lie ahead—what is the advanced thinking in our university and industrial and Government laboratories, and some of the things now currently programed that merit study.

Since I consider the major laboratories of the Atomic Energy Commission one of foremost national assets, we should question the adequacy of the long-range programing for these installations in their roles as fixed and permanent national institutions.

The scope of the survey would probably include consideration of the following advanced fields: Advanced power reactor types, such as breeders; advanced applications of nuclear reactors as heat sources, including direct conversion of heat to electricity and conversion of saline water to pure water; atomic power for outer space propulsion; controlled thermonuclear power; "plowshare" applications of bomb explosions to peaceful uses; utilization of solar energy; and use of the earth's heat from radioactive processes. The survey might also consider other civilian applications of military devices.

While any panel or subcommittee of the Joint Committee is free to decide its own methods, I would suggest that they first gather as many ideas as possible before they evaluate them. I suspect that many ideas are not getting through from the laboratories and industry to the policymakers. If the survey were no more than a sounding board or forum for the dissemination of new ideas, it will have succeeded.

When the survey has been concluded, I would hope that the report would contain a 10-year and a 20-year statement of scientific and technical objectives in atomic energy and related fields setting out the desirable level of basic research and proposed new applications.

EPILOG

I believe you will agree that the Joint Committee and its staff and consultants will be reasonably busy during the next 2 years if we undertake consideration of the matters I have outlined in this article.

Such efforts will have been worthwhile if we can point the way more clearly in chaneling the elemental force of atomic energy from the fields of weaponry to enhancing our civilian way of life with increasing benefits for all mankind.

APPENDIX 4

[Reprinted from Forum Memo, December 1958]

FOUR A-POWER APPROACHES

The following four tentative approaches to atomic power development in the United States, as put forth by the Edison Electric Institute, the AEC, the JCAE, and the General Electric Co., are tabulated below for comparative purposes.

EDISON ELECTRIC INSTITUTE

The EEI in March 1958 listed the following reactors as warranted for consideration for construction within the approximate time intervals indicated.

Boiling water, with nuclear superheat, 10 to 50 electrical megawatts, 1958–62.
Gas cooled, graphite moderated, 50 electrical megawatts, 1959–63.
Aqueous homogeneous solution, 75 to 150 electrical megawatts, 1959–64.
Fused salt fueled, 10 electrical megawatts, 1959–64.
Steam cooled, D_2O moderated, 10 electrical megawatts, 1959–65.
Intermediate energy neutron breeder, 10 electrical megawatts, 1958–67.
PWR, enriched uranium fuel, 200 electrical megawatts, 1959–65.
BWR, enriched uranium fuel, 200 electrical megawatts, 1960–66.
H_2O cooled, graphite moderated, Hanford type, 250 electrical megawatts, 1959–66.
D_2O cooled and moderated, Savannah River type, natural uranium, 250 electrical megawatts, 1960–67.
Sodium cooled, graphite moderated, 200 electrical megawatts, 1961–67.

ATOMIC ENERGY COMMISSION

Last June the AEC put the following proposed U.S. power program into the record in hearings before the Joint Committee on Atomic Energy. The program is currently under review by an ad hoc advisory committee. The dates given are approximate projected initiation dates.

Modification of borax and EBWR, fiscal year 1959.
Construction of the Elk River boiling reactor plant, fiscal year 1959.
Construction of the Piqua organic moderated plant, fiscal year 1959.
Construction of a heavy-water-components test reactor at Savannah River, fiscal year 1959.
Preliminary design of a 100-electrical-megawatt heavy-water powerplant, fiscal year 1959.
Construction of a 40-electrical-megawatt experimental gas-cooled reactor prototype, fiscal year 1959.
Construction of the LMFRE–1, fiscal year 1959.
Selection of a new reactor concept from among 10 to 12 available for further research and development, fiscal year 1959.
Construction of the 100-electrical-megwatt heavy-water reactor, fiscal year 1960.
Possible construction of the P.P. & L.-Westinghouse reactor, fiscal year 1960.
Design of an intermediate-sized two-region aqueous homogeneous reactor experiment, fiscal year 1960.
Construction of a 20–40-electrical-megawatt PWR, fiscal year 1960.
Major modifications SRE core, possible initiation of design on an SRE–2, fiscal year 1960.
Construction of a second organic-moderated reactor experiment, fiscal year 1960.
Construction of the East Central-Florida West Coast gas-cooled heavy-water reactor, fiscal year 1960.
Construction of the Carolinas-Virginia heavy-water reactor, fiscal year 1960.
Construction of the Chugach, Alaska, heavy-water sodium-cooled reactor, fiscal year 1960.
Possible construction of an intermediate-sized reactor using molten salt as fuel, fiscal year 1960.
Construction of a low-temperature process heat prototype plant, fiscal year 1960.
Possible construction of 2 to 4 large-scale and 1 or 2 small-scale boiling and nonboiling water reactors, fiscal years 1961–63.
Possible construction of SRE–2, possible design of a second-generation large-scale sodium-cooled power plant, fiscal years 1961–63.
Possible construction of a second-generation fast breeder; possible construction of an EBR–3, fiscal years 1961–63.
Possible construction of additional small- and large-scale organic-moderated plants, fiscal years 1961–63.
Possible construction of additional gas-cooled plants, fiscal years 1961–63.
Initiation of operation of the plutonium testing reactor and the large-scale heavy-water reactor using natural uranium, fiscal years 1961–63.
Possible construction of an LMFRE–2, fiscal years 1961–63.
Possible construction of one or more process heat plants of pilot size or larger, fiscal years 1961–63.
Possible construction of one or more reactor experiments to test new concepts, fiscal years 1961–63.

JOINT COMMITTEE ON ATOMIC ENERGY

Last August the Joint Committee on Atomic Energy proposed the following tentative power program with the statement that "about half of these projects will show enough technical and economic potential to warrant construction" in the approximate time intervals indicated.

Heavy-water cooled and moderated power components reactor, 60 electrical megawatts, for completion 1958–60.
Gas cooled, graphite moderated, 40 electrical megawatts, 1958–62.
Boiling water with nuclear superheat, 10 to 50 electrical megawatts, 1958–62.
Aqueous homogeneous solution, 75 to 150 electrical megawatts, 1959–65.
Process heat reactor, 45 electrical megawatts, 1959–62.
Fused salt fueled, 10 electrical megawatts, 1959–64.

Steam cooled, heavy water moderated, 10 electrical megawatts, 1959–65.
Intermediate energy neutron breeder, 10 electrical megawatts, 1958–67.
Water cooled, graphite moderated, Hanford type, 300 electrical megawatts, 1958–63.
Pressurized water, enriched uranium fuel, 200 electrical megawatts, 1959–64.
Boiling water, enriched uranium fuel, 200 electrical megawatts, 1960–65.
Organic cooled reactor, 50 electrical megawatts, 1960–64.
Liquid-metal-fueled reactor experiment, 5 electrical megawatts, 1959–63.
Two small second generation industrial plants, 15–40 electrical megawatts, 1961–65.
High temperature gas cooled, graphite or heavy water moderated, 200 electrical megawatts, 1961–66.
High temperature sodium cooled, graphite or D_2O moderated, 200 electrical megawatts, 1961–66.
Organic cooled reactor, 200 electrical megawatts, 1962–67.
Sodium cooled fast or intermediate breeder, 200 electrical megawatts 1963–68.
Liquid metal fueled reactor, 50 electrical megawatts, 1963–68.

GENERAL ELECTRIC

In September 1958 General Electric proposed the following program to the U.S. utility industry as Operations "Know-How" and "Sunrise," all plants to be of the boiling water type.

Up to 50 BWR plants designed for 5 electrical megawatts delivery to start in 1960.
A 50-electrical-megawatt plant to exploit the cost reduction potential of system simplification, for completion by 1962.
A 25-electrical-megawatt plant to study cost cuts through reduction in physical size, by 1962.
A 25-electrical-megawatt plant to prove out possibilities of reducing capital cost by doubling power output per unit reactor core volume, by 1962.
A 100-electrical-megawatt or larger plant to test power density limits obtainable in a medium sized reactor, by 1962.
A 50-electrical-megawatt plant to be used as a "hook-on" to an existing BWR to demonstrate characteristics of a superheating reactor in conjunction with BWR's, by 1962.
"Evolutionary" plants, possibly a 100-electrical-megawatt natural circulation plant, a 200-electrical-megawatt forced circulation plant, and a 325-electrical-megawatt superheater plant, by 1965.
Three "target" plants, possibly in the 450-electrical-megawatt range, by 1970.

APPENDIX 5

THE ATOMIC INDUSTRY – 1958 – Prepared by the Atomic Industrial Forum

A PROGRESS REPORT
OUTLINING THE ROLE OF AMERICAN INDUSTRY
IN DEVELOPING THE COMMERCIAL APPLICATIONS OF ATOMIC ENERGY

The United States during 1958 completed 38 nuclear reactors in this country and abroad, in addition to reactors which may have been completed in the classified aircraft nuclear propulsion program.

Highlighting the reactors completed were the atomic engines for the new atomic submarines *Swordfish* and *Sargo*, a dual-reactor land-based prototype of the U.S.'s first atomic powerplant for a large naval surface vessel, a single-reactor land-based prototype for an advanced atomic submarine engine, and a ground-test experiment of a nuclear reactor designed for rocket propulsion.

Also completed during the year were a small, transportable reactor designed to produce both electric power and heat for remote Army bases, and three powerful test reactors in which atomic construction materials and fuels can be subjected to the rigorous temperature and irradiation conditions to be met in the nuclear power plants of the future.

The remaining reactors completed during the year include one small power experiment and 27 relatively small research and training devices.

The year 1958 also saw the U.S. begin construction on 45 reactors in the U.S. and abroad, including two reactors which will produce electric power for distribution to consumers in the states of Nebraska and Minnesota, a small reactor which will provide electricity and space heat for an Army post in Alaska, 13 reactors to propel submarines, an atomic engine for a naval destroyer and a land-based prototype for the destroyer engine, three large test reactors, and two small power experiment reactors.

U.S. industry also received new contracts or letters of intent during the year for the construction overseas of three reactors to produce electric power, including a large reactor to be built for the Italian government with financial assistance from the International Bank for Reconstruction and Development (World Bank) and two smaller reactors to be built in Cuba and West Germany.

In the radiation applications field, 186 industrial firms started using radioactive isotopes for the first time in 1958. These firms, and others already using radioactive materials, accounted for an increase of 71 in the application of thickness or density gages and an increase of 12 in other gages during the year. 36 industrial organizations obtained an AEC general authorization to use radioactive materials for any research and development work and 30 obtained material for processing into products for resale. Firms engaged in food and agriculture showed the highest percentage increase in new organizations primarily due to the increased use of density gages to measure specific gravity of foods in liquid form inside pipes. California's industrial users increased by 39, passing New York to become the leading state in industrial use of radioactive isotopes. A total of eight states have more than 100 industrial firms using radioisotopes and in addition four states have more than 50 but less than 100 such firms. As of the end of the year, 65 organizations had been licensed by the AEC for high level gamma facilities each having at least 100 curies of cobalt-60. Of the 81 sources of over 100 curies, 10 contain more than 15,000 curies of cobalt-60 each, with the total activity of all such large sources coming to about 430,000 curies.

Other highlights of the year include the completion of 11 new U.S. uranium ore mills, the sale of at least 39 particle accelerators, and the completion of two new facilities for preparing nuclear reactor fuel.

REACTOR ACTIVITIES

POWER REACTORS

Newly completed: During 1958 one power producing reactor came into operation in the U.S. – a 200 electrical kilowatt (ekw) boiling water power-and-space-heat reactor built by Argonne National Laboratory for the AEC near Idaho Falls, Idaho. Combustion Engineering, Inc. will operate the reactor under AEC contract.

Began construction: Construction began during the year on the following three power reactors:

1. A 75,000 ekw sodium graphite reactor being built by North American Aviation, Inc. for the AEC, for operation by Consumers Public Power District of Nebraska, scheduled for completion in 1960 at Hallam, Nebr.

2. A 22,000 ekw boiling water reactor plant (including conventional superheat) being built by ACF Industries, Inc. for the AEC, for operation by the Rural Cooperative Power Association of Elk River, Minn., scheduled for completion in 1960 at Elk River.

3. A 1,700 ekw pressurized power-and-space-heat reactor being built by Peter Kiewit Sons Co., with the nuclear system to be provided by Alco Products, Inc. for the Army Corps of Engineers, scheduled for completion in 1960 at Fort Greely, Alaska.

Continued Operation: The following seven U.S. nuclear power plants which were completed in earlier years continued operation in 1958:

1. A 60,000 electrical kilowatt pressurized water reactor built by Westinghouse Electric Corp. for the AEC, for operation by Duquesne Light Co., completed in 1957 at Shippingport, Pa.

2. A 6,200 ekw experimental boiling water reactor, completed by Argonne National Laboratory in 1956 at Chicago, Ill.

3. A 6,000 ekw sodium graphite reactor built by North American Aviation, Inc. for the AEC, completed in 1957 at Santa Susana, Cal.

4. A 5,000 ekw boiling water reactor built by General Electric Co. on its behalf, completed in 1957 at Vallecitos, Cal.

5. A 2,000 ekw pressurized water reactor built by Alco Products, Inc. for the Army and the AEC, completed in 1957 at Fairfax, Va.

6. A 300 ekw homogeneous reactor experiment completed by Oak Ridge National Laboratory in 1957 at Oak Ridge, Tenn.

7. A 200 ekw experimental breeder reactor completed by Argonne National Laboratory in 1951 near Idaho Falls, Idaho.

Continued construction: Construction initiated prior to 1958 continued during the year on the following five plants:

1. A 180,000 ekw boiling water reactor being built by General Electric Co. for Commonwealth Edison Co. of Chicago, scheduled for completion in 1959-1960 at Dresden, Ill.

2. A 163,000 ekw pressurized water reactor, with conventional superheat, being built by the Babcock & Wilcox Co. for Consolidated Edison Co. of New York, scheduled for completion in 1960 at Indian Point, N. Y.

3. A 134,000 ekw pressurized water reactor being built by Westinghouse Electric Corp. for Yankee Atomic Electric Co., scheduled for completion in 1960 at Rowe, Mass.

4. A 100,000 ekw fast neutron reactor being built by Power Reactor Development Co. on its own behalf, scheduled for completion in 1960 at Lagoona Beach, Mich.

5. A 20,000 ekw experimental breeder reactor being built by Argonne National Laboratory, scheduled for completion in 1960 near Idaho Falls, Idaho.

Began preconstruction development: Development work expected to lead to construction began during the year on the following two power reactors:

1. A 60,000 ekw boiling water reactor to be built by Bechtel Corp., with General Electric Co. as the nuclear system supplier, for Pacific Gas & Electric Co., scheduled for completion in 1962 at Eureka, Cal.

2. A plutonium production reactor to be capable of later conversion for the production of 300,000 kilowatts of electric power, being designed and developed by General Electric Co. on behalf of the AEC.

Continued preconstruction development: Development work expected to lead to construction continued during the year on the following five reactors.

1. A 66,000 ekw boiling water reactor plant (with nuclear superheat) to be built by Allis-Chalmers Manufacturing Co. for Northern States Power Co., scheduled for completion in 1962 at Sioux Falls, S.D.

2. A 50,000 ekw heavy water moderated, gas cooled reactor for construction by the East Central Nuclear Group and the Florida West Coast Nuclear Group on their own behalf, scheduled for completion in 1963 in West Florida.

3. A 17,000 ekw pressurized heavy water reactor to be built by Westinghouse Electric Corp. for Carolinas Virginia Nuclear Power Associates, scheduled for completion in 1962 at Parr Shoals, S. C.

4. A 12,500 ekw organic moderated reactor to be built by North American Aviation, Inc. for the AEC, for operation by the City of Piqua, Ohio, scheduled for operation in 1961 in Piqua.

5. A 10,000 ekw sodium-heavy water reactor to be built by Nuclear Development Corp. of America for the AEC, for operation by the Chugach Electric Association of Anchorage, Alaska, scheduled for completion by 1962, contingent on the outcome of research and development studies.

Plans announced: AEC announced plans for the following two power reactors which were authorized in 1958 by Congress. At the end of 1958 industrial bids had been sought and received for both projects, but contractors had not yet been selected.

1. A 30,000-60,000 ekw prototype gas cooled, graphite moderated, high temperature reactor on which Congress has set a completion deadline of December 31, 1962. The only proposal came from Philadelphia Electric Co. in association with a group of utilities known as High Temperature Reactor Development Associates, specifying Bechtel Corp. as prime contractor and General Dynamics Corp. as reactor builder. The proposed reactor location is Peach Bottom, Pa.

2. A pressurized water reactor to produce 1,000 kw of electricity and 2,000 kw of space heat, scheduled for completion in 1961 at the Sundance Air Force Station in Sundance, Wyo.

Plans canceled: Pennsylvania Power & Light Co. and Westinghouse Electric Corp. announced the cancellation

of plans to build a 70,000-150,000 ekw aqueous homogeneous reactor.

Began new studies: During the year the following U.S. companies received new contracts for the study of power reactor concepts:

1. American Radiator & Standard Sanitary Corp. for a study of a mercury cooled fast reactor on behalf of the AEC.

2. Babcock & Wilcox Co. for a study of a gas suspension reactor on behalf of the AEC.

3. Bechtel Corp., with North American Aviation, Inc. as nuclear subcontractor, for a study of an organic cooled reactor on behalf of the AEC.

4. Curtiss-Wright Corp. for a study of compact, mobile nuclear power plants of up to 2,000 ekw for military use.

5. Ebasco Services, Inc. with General Electric Co. as nuclear subcontractor, for a study of a boiling water reactor on behalf of the AEC.

6. General Dynamics Corp. for a study of gas cooled reactors on behalf of the Rocky Mountain-Pacific Nuclear Research Group (an association of eight utility companies) and on behalf of San Diego Gas & Electric Corp.

7. General Electric Co. for a study of a sodium graphite reactor in which the fuel and coolant would be contained in modules, on behalf of the AEC.

8. General Electric Co. for a study of compact, mobile nuclear power plants of up to 2,000 ekw for military use.

9. General Motors Corp. and Nuclear Development Corp. of America for a study of compact, mobile nuclear power plants of up to 2,000 ekw for military use.

10. General Nuclear Engineering Corp. for a study of a 15,000 ekw boiling water reactor with nuclear superheat on behalf of AEC and the Puerto Rico Water Resources Authority.

11. The Martin Co. for a study of fluidized bed reactors on behalf of the AEC.

12. North American Aviation, Inc. for a study of a sodium cooled thorium breeder reactor on behalf of Southwest Atomic Power Associates (a group of 15 utility companies).

13. Sargent & Lundy, with Nuclear Development Corp. of America as nuclear subcontractor, for a study of a heavy water moderated reactor on behalf of the AEC.

14. Stone & Webster Engineering Corp., with Combustion Engineering, Inc. as nuclear subcontractor, for a study of a pressurized water reactor on behalf of the AEC.

15. Westinghouse Electric Corp. for a study of an organic moderated fluidized bed reactor on behalf of the City of Burlington, Vt.

Continued studies: The following power reactor studies begun in previous years were continued during 1958:

1. Alco Products, Inc. and Sanderson & Porter who are studying a gas cooled pellet bed reactor concept on their own behalf.

2. Du Pont Co. which is studying heavy water reactors on behalf of the AEC.

3. General Public Utilities Corp. which is investigating the possible construction of a small water type reactor at Saxton, Pa. (In January 1959 G.P.U. awarded a contract to Westinghouse Electric Corp. for a 5,000 ekw pressurized water reactor to be installed at Saxton, Pa.)

4. New England Electric System which is investigating the possible construction of a 200,000 ekw reactor plant by 1964.

POWER REACTOR EXPERIMENTS

Reactors listed in this section are designed to lead to power uses but do not themselves produce power.

Newly completed: Los Alamos Scientific Laboratory completed a homogeneous reactor experiment for the AEC during 1958 at Los Alamos, N.M.

Began construction: Construction began during the year on the following two experimental reactors which are designed to lead to power uses but do not themselves produce power:

1. A gas cooled package power reactor experiment being built by Aerojet-General Corp. for the AEC, scheduled for completion in 1959 near Idaho Falls, Idaho.

2. A fast molten plutonium reactor being built by Los Alamos Scientific Laboratory for the AEC, scheduled for completion in 1960 at Los Alamos, N.M.

Continued operation: The following two experimental reactors for power uses completed in earlier years continued operation:

1. An organic moderated reactor built by North American Aviation, Inc. for the AEC, completed in 1957 near Idaho Falls, Idaho.

2. A boiling water reactor experiment known as BORAX-IV, completed in 1956 by Argonne National Laboratory for the AEC near Idaho Falls, Idaho.

Continued preconstruction development: During the year the Babcock & Wilcox Co. continued development of a liquid metal fueled reactor experiment on behalf of the AEC.

U.S. POWER REACTORS SOLD ABROAD

New contracts: U.S. industrial concerns received new contracts or letters of intent for the following three boiling water power reactors for installation abroad:

1. A 150,000 ekw plant to be built by General Electric Co. for Societa Elettronucleare Nazionale (SENN), scheduled for completion in late 1962 or early 1963 at Punta Fiume in Italy. The project will be partially financed by the International Bank for Reconstruction and Development, and the contractor was selected from among 11 bids from the U.S., Britain and France in a bidding procedure supervised by the World Bank and the Italian government.

2. A 22,000 ekw plant, with conventional superheat, to be built by American Machine & Foundry Co., in partnership with Mitchell Engineering Ltd. of Britain, for the Cuban National Bank for Social and Economical Development, scheduled for completion in 1961 at Santa Lucia in Cuba.

3. A 15,000 ekw plant to be built by General Electric Co. for Rheinisch-Westfalisches Elektrizitatswerk (RWE), with Allgemeine Elektrizitats-Gesellschaft as the prime contractor, scheduled for completion in 1960 at Kahl, West Germany.

Continued construction: Westinghouse Electric Corp. continued the manufacture and began the export of components for an 11,800 ekw pressurized water reactor being built for the Centre d'Etudes de l'Energie Nucleaire, scheduled for completion in 1959 at Mol, Belgium.

Plans announced: During the year the following new plans were announced for the purchase of U.S. power reactors by other nations:

1. The Swiss firm of Brown Boveri was reported to have tentative plans for the purchase of a 21,000 ekw pressurized water reactor from Babcock & Wilcox Co. for installation near Lima, Peru.

2. North American Aviation, Inc. received a contract from the Spanish governmental Junta de Energia Nuclear for a feasibility study of a heavy water moderated, organic cooled reactor to produce 20,000 ekw, to produce radioisotopes, and to provide reactor fuel testing facilities.

3. Suisatom, S.A., an association of utilities in Switzerland, announced plans to purchase a 16,000 ekw boiling water reactor with General Electric Co. supplying the design and nuclear components.

4. The Japan Atomic Energy Research Institute announced plans to purchase a 10,000 ekw boiling or pressurized water reactor for installation at Tokai, Japan. During the year the Institute received eight industrial proposals to build the reactor and awarded a contract to Internuclear Co. for consulting services regarding the selection of a reactor builder.

Plans continued: The following plans announced prior to 1958 to purchase U.S. power reactors for installation abroad continued in force during the year:

1. Westinghouse Electric Corp. holds a letter of intent for a 134,000 ekw pressurized water reactor to be built for the Societa Elettronucleare Italiana (SELNI) near Milan, Italy.

2. Vitro Corp. of America holds a contract with AGIP Nucleare of Italy for design and consulting services for a 150,000 ekw plant of unespecified type, to be purchased from a U.S. manufacturer.

Plans suspended: American & Foreign Power Co. announced during the year that it is suspending indefinitely its plans to build small power reactors in Brazil, Cuba and Mexico. Two of the reactors were to be of the boiling water type, manufactured by General Electric Co., and the third was to be of the organic moderated type, manufactured by North American Aviation, Inc.

PROCESS HEAT REACTORS

Began new studies: During the year the following two companies began studies of process heat reactors:

1. Michigan Chemical Corp. which is investigating the possibility of purchasing a 45,000 thermal kilowatt process heat reactor of the pressurized water type from the Martin Co. in association with H. K. Ferguson Co., subject to AEC financial assistance.

2. American Hydrotherm Corp. which is studying process heat reactors under AEC contract.

MERCHANT SHIP REACTORS

Continued construction: The Babcock & Wilcox Co. continued construction of a 74,000 thermal kilowatt pressurized water reactor for installation in the *N.S. Savannah*, the U.S.'s first nuclear powered merchant ship, which is scheduled for completion in 1960. A replacement core for the *Savannah* reactor is being fabricated by General Electric Co.

Began new studies: The following two companies began studies of merchant ship propulsion reactors during the year under AEC contract:

1. General Dynamics Corp. for a gas cooled reactor for use in association with a gas turbine.

2. General Electric Co. for a boiling water reactor for possible installation in an oil tanker.

NAVY PROPULSION REACTORS

Newly completed: The following five propulsion or prototype propulsion reactors for naval vessels were completed during 1958:

Two pressurized water reactors built by Westinghouse Electric Corp. to propel the attack submarines *Swordfish* and *Sargo*.

Two pressurized water reactors built by Westinghouse near Idaho Falls, Idaho as a prototype propulsion plant for large naval surface vessels.

One pressurized water reactor built by General Electric Co. at West Milton, N.Y. as a prototype of the reactor to propel the radar picket submarine *Triton*.

Began construction: Construction began during the year on the following 15 new naval propulsion reactors or prototypes:

Thirteen pressurized water reactors being built by Westinghouse Electric Corp. to propel the fast attack submarines *Thresher, SSN 603, SSN 604, SSN 605,* and *SSN 606;* the British attack submarine *Dreadnought;* the the submarine *Seawolf* (to be converted from its present sodium cooled reactor); the guided missile submarine *SSG(N) 607;* and the fleet ballistic missile submarines *George Washington, Patrick Henry, Theodore Roosevelt, Robert E. Lee* and *Abraham Lincoln*.

Two pressurized water reactors being built by General Electric Co. – one at West Milton, N.Y. to serve as a prototype for the propulsion of a large destroyer, and one for actual installation in a destroyer.

Continued operation: During the year operation continued of the following four naval propulsion reactors and prototypes completed in previous years:

Three pressurized water reactors built by Westinghouse Electric Corp. – two to propel the submarines *Nautilus* and *Skate*, and one built at Idaho Falls, Idaho as a prototype for the *Nautilus*.

One sodium cooled reactor built by General Electric Co. to propel the submarine *Seawolf*.

Continued construction: During the year construction continued on the following 25 naval propulsion reactors begun in previous years:

Eleven pressurized water reactors being built by Westinghouse Electric Corp. for installation in the attack submarines *Seadragon, Skipjack, Scamp, Scorpion, Sculpin, Shark* and *Snook;* and the guided missile submarines *Halibut, Permit, Pollack* and *Plunger*.

Ten pressurized water reactors being built by Westinghouse – eight for installation in the aircraft carrier *Enterprise* and two for installation in the cruiser *Long Beach*.

Two pressurized water reactors being built by Combustion Engineering, Inc. – one as a prototype to propel the small attack submarine *Tullibee*, and the other for actual installation in the *Tullibee*.

Two pressurized water reactors being built by General Electric Co. for installation in the radar picket submarine *Triton*.

AIRCRAFT PROPULSION REACTORS

General Electric Co. and Pratt & Whitney Aircraft continued work on the development of reactors for the propulsion of military aircraft, under AEC contract. At least two experimental General Electric reactors were in operation during the year at Idaho Falls, Idaho, one of which was damaged in a November accident.

Martin Co. received a Navy contract to study the possibility of installing a propulsion reactor in a flying test.

Information concerning the development of nuclear powered aircraft is almost completely classified.

ROCKETS AND MISSILES

During the year Los Alamos Scientific Laboratory and Livermore (Cal.) Laboratory, both of which are operated for the AEC by the University of California, carried forward the development of nuclear powered rockets and ramjet missiles. At the end of the year an experimental ground test reactor known as Kiwi-A was being readied for testing in Nevada as part of the Los Alamos nuclear rocket program.

Industrial companies holding Air Force development contracts in the field include: North American Aviation, Inc., Aerojet-General Corp., ACF Industries, Inc., Edgerton, Germeshausen & Grier, Curtiss-Wright Corp., and Marquardt Aircraft.

General Dynamics Corp. received a contract during the year for a study of the feasibility of propulsion in space by means of small controlled nuclear explosions.

MATERIALS TESTING REACTORS

The reactors listed in this section are those which have relatively high thermal power level and neutron flux and are designed specifically for testing reactor materials, fuels and components.

Newly completed: The following three materials testing reactors were completed during the year by U.S. industrial concerns:

1. A 30,000 thermal kilowatt reactor built by General Electric Co. at Vallecitos, Cal. for its own use.

2. A 20,000 tkw test reactor built by Oak Ridge National Laboratory (which is operated by Union Carbide Nuclear Co.) on behalf of the AEC at Oak Ridge, Tenn.

3. A 10,000 tkw radiation effects reactor built by Lockheed Aircraft Corp. and General Electric Co. at Dawsonville, Ga. on behalf of the Air Force.

Began construction: Construction began on the following three testing reactors:

1. A 70,000 thermal kw plutonium recycle test reactor being built by General Electric Co. for AEC, scheduled for completion in 1960 at Hanford, Wash.

2. A 61,000 tkw heavy water component test reactor being built by the Du Pont Co. for the AEC, scheduled for completion in 1960 at Savannah River, S.C.

3. A 60,000 tkw test reactor being built by the National Aeronautics and Space Administration for its own use, scheduled for completion in 1960 at Sandusky, Ohio.

Continued operation: The following two test reactors completed in earlier years continued in operation in 1958:

1. A 175,000 tkw test reactor completed in 1957 by Kaiser Engineers and General Electric Co. on behalf of the AEC at Idaho Falls, Idaho.

2. A 40,000 tkw test reactor completed in 1952 by Flour Corp. and Oak Ridge National Laboratory on behalf of the AEC at Idaho Falls, Idaho.

Continued construction: Construction continued on the following two test reactors begun in previous years:

1. A 20,000 tkw test reactor being built by Westinghouse Electric Corp. for its own use, scheduled for completion in 1959 at Waltz Mill, Pa.

2. A 10,000 tkw test reactor being built by ACF Industries, Inc. on behalf of the Air Force, scheduled for completion in 1959 at Dayton, Ohio.

Test reactors under construction abroad: The following three materials testing reactors are under construction abroad with U.S. industrial assistance:

1. A 30,000 tkw test reactor being built for Sweden by ACF Industries, Inc.

2. A 25,000 tkw test reactor being built in Belgium for which Nuclear Development Corp. of America is the designer and principal supply agent.

3. A 20,000 tkw test reactor being built for the Netherlands by ACF Industries, Inc.

Plans announced: Plans were announced during the year for the following three test reactors:

1. A 50,000 tkw test reactor to be built by General Electric Co. on behalf of Industrial Testing Reactors, Inc., to be completed by 1960-61 in North Carolina.

2. A high flux 20,000 tkw heavy water reactor to be built by Brookhaven National Laboratory for its own use at Upton, N.Y.

3. A 10,000 tkw test reactor to be built by Aerojet-General Nucleonics at San Ramon, Cal.

Plans continued: A group composed of ACF Industries, Inc., Kaiser Engineers, Lockheed Aircraft Corp. and Phillips Petroleum Co. continued to investigate the possibility of building a testing reactor.

Plans suspended: Case Institute of Technology and a group of industrial sponsors suspended an investigation of the possibility of building a testing reactor.

RESEARCH REACTORS

The reactors described in this section are rated at 100 kilowatts of thermal power or greater but do not include high flux reactors for testing materials and components. Reactors smaller than 100 tkw, and materials testing reactors, are each treated in separate sections.

Newly completed: The following U.S. research reactors were completed during the year:

1. A 60,000 tkw (maximum) pressurized water power excursion test reactor built by Phillips Petroleum Co. for its own use on behalf of the AEC at Idaho Falls, Idaho.

2. A 5,000 tkw heavy water reactor built by ACF Industries, Inc. for the Massachusetts Institute of Technology at Cambridge, Mass.

3. A 5,000 tkw pool type reactor built by American Machine & Foundry Co. for Industrial Reactor Laboratories, Inc. at Plainsboro, N.J.

4. A 1,000 tkw pool type reactor built by Curtiss-Wright Corp. for its own use at Quehanna, Pa.

5. A 100 tkw tank type reactor built by Brookhaven National Laboratory for its own use at Upton, N.Y.

Began construction: Construction began during the year on the following U.S. research reactors:

1. A 1,000 tkw pool type reactor being built by Curtiss-Wright Corp. for the U.S. Army's Ordnance Materials Research Office at Watertown, Mass.

2. A 1,000 tkw pool type reactor being built by

American Machine & Foundry Co. for the AEC at Mayaguez, Puerto Rico.

3. A 1,000 tkw pool type reactor built by the University of Virginia for its own use at Charlottesville, Va.

4. A 100 tkw pool type reactor being built by General Electric Co. for its own use on behalf of the AEC at Idaho Falls, Idaho.

Continued operation: The following U.S. research reactors completed in earlier years continued operation in 1958:

1. A 30,000 tkw air cooled, graphite moderated reactor completed in 1950 by Brookhaven National Laboratory for its own use at Upton, N.Y.

2. A 3,800 tkw air cooled, graphite moderated reactor completed in 1943 by what is now Oak Ridge National Laboratory for its own use at Oak Ridge, Tenn.

3. A 3,000 tkw tank type reactor completed in 1950 by Oak Ridge National Laboratory for its own use at Oak Ridge, Tenn.

4. A 2,000 tkw heavy water research reactor completed in 1954 by Argonne National Laboratory for its own use at Lemont, Ill.

5. A 1,000 tkw pool type reactor completed in 1956 by American Machine & Foundry Co. for Battelle Memorial Institute in West Jefferson, Ohio.

6. A 1,000 tkw tank type reactor completed in 1956 by Los Alamos Scientific Laboratory for its own use at Los Alamos, N.M.

7. A 1,000 tkw pool type reactor completed in 1957 by Babcock & Wilcox Co. for the University of Michigan at Ann Arbor, Mich.

8. A 1,000 tkw tank type reactor completed in 1957 by Foster Wheeler Corp. for AEC's Livermore Laboratory at Livermore, Cal.

9. A 1,000 tkw light water reactor completed in 1954 by Convair Division of General Dynamics Corp. for its own use on behalf of the Air Force at Oak Ridge, Tenn.

10. A 500 tkw pool type reactor completed in 1950 by Oak Ridge National Laboratory for its own use at Oak Ridge, Tenn.

11. A 500 tkw pool reactor completed in 1953 by the Convair Division of General Dynamics Corp. for its own use on behalf of the Air Force at Fort Worth, Texas.

12. A 500 tkw tank type reactor completed in 1954 by Oak Ridge National Laboratory for its own use at Oak Ridge, Tenn.

13. A 100 tkw pool type reactor completed in 1955 by Pennsylvania State University for its own use at University Park, Pa.

14. A 100 tkw pool type reactor completed in 1956 by the Naval Research Laboratory for its own use at Washington, D.C.

15. A 50 tkw homogeneous reactor completed in 1956 by North American Aviation, Inc. for Armour Research Foundation at Chicago, Ill.

16. A tank type reactor of unspecified power level for power excursion experiments completed in 1955 by Phillips Petroleum Co. for its own use on behalf of the AEC at Idaho Falls, Idaho.

Continued construction: Construction continued during 1958 on the following U.S. research reactors previously begun:

1. A 5,000 tkw pool type reactor being built by American Machine & Foundry Co. for Union Carbide Nuclear Co. at Sterling Forest, N.Y.

2. A 5,000 tkw light water reactor being built by Oak Ridge National Laboratory for its own use at Oak Ridge, Tenn.

3. A 1,000 tkw tank type medical reactor being built by Brookhaven National Laboratory for its own use, with Daystrom, Inc. supplying the core and instrumentation, at Upton, N.Y.

4. A 100 tkw graphite reactor for transient tests being built by Argonne National Laboratory for its own use at Idaho Falls, Idaho.

5. A pressurized water reactor of unspecified power level for power excursion experiments being built by Phillips Petroleum Co. for its own use on behalf of the AEC at Idaho Falls, Idaho.

Plans announced: New plans were announced during the year for the following U.S. research reactors:

1. A 5,000 tkw tank type reactor to be built by Sandia Corp. for its own use at AEC's Sandia Base near Albuquerque, N.M.

2. A 5,000 tkw pool type reactor for the Texas Agricultural and Mechanical College.

3. A heavy water reactor of unspecified size to be built for AEC's Ames, Iowa laboratory.

4. A reactor of unspecified type to be built for the state of Rhode Island.

5. A reactor of unspecified size and type to be built by Argonne National Laboratory for its own use.

6. A reactor of unspecified size and type for the University of Tennessee.

The Air Force Cambridge Research Center also announced that it had awarded a contract to ACF Industries, Inc. for a survey of the Center's needs for a research reactor to be located at Bedford, Mass.

Plans continued: Plans announced in previous years for the following U.S. research reactors continued in force during 1958:

1. A 1,000 tkw pool type reactor to be built by American Machine & Foundry Co. for the University of Buffalo at Buffalo, N.Y.

2. A 1,000 tkw pool type reactor to be built by General Electric Co. for the State College of Washington at Pullman, Wash.

3. A heavy water research reactor of unspecified size to be built for Georgia Institute of Technology.

U.S. RESEARCH REACTORS SOLD ABROAD

Newly completed: Research reactors completed abroad by U.S. industrial firms during 1958 are the following:

1. A 5,000 tkw pool type reactor built by Babcock & Wilcox Co. at Hamburg, West Germany.

2. A 3,000 tkw pool type reactor built by General Electric Co. at Moncloa, Spain.

Began construction: New orders were received and/or construction began during 1958 on the following research reactors to be built abroad by U.S. industry:

1. A 5,000 tkw tank type reactor being built by American Machine & Foundry Co. for the Austrian Study Co. for Atomic Energy at Vienna, Austria.

2. A 1,000 tkw pool type reactor to be built by Curtiss-Wright Corp. for the University of Chulalongkorn in Bangkok, Thailand.

3. A 1,000 tkw pool type reactor being built by General Electric Co. for the National Tsing-Hua University at Taipei, Formosa.

4. A 1,000 tkw pool type reactor being built by American Machine & Foundry Co. for the Israel Atomic Commission at Tel Aviv, Israel.

5. A 1,000 tkw pool type reactor being built by American Machine & Foundry Co. for the University of Teheran at Amirabad, Iran.

Continued construction: Construction continued on the following research reactors began during previous years at overseas locations by U.S. firms:

1. A 10,000 tkw heavy water reactor being built by American Machine & Foundry Co. for the Japan Atomic Energy Research Institute in Tokai, Japan.

2. A 5,000 tkw heavy water reactor being built by ACF Industries, Inc. for the Comitato Nazionale per le Ricerche Nucleari at Ispra, Italy.

3. A 5,000 tkw tank type reactor being built by Foster Wheeler Corp. for the Danish Atomic Energy Commission at Risoe, Denmark.

4. A 3,000 tkw pool type reactor being built by General Electric Co. for the Instituto Venezolano de Investigaciones Cientificas of Caracas, Venezuela.

5. A 1,000 tkw pool type reactor being built by American Machine & Foundry Co. for the Societa Ricerche Impianti Nucleari of Milan, Italy.

6. A 1,000 tkw pool type reactor being built by American Machine & Foundry Co. for the Greek Atomic Energy Commission at Athens, Greece.

7. A 1,000 tkw pool type reactor being built by American Machine & Foundry Co. for the Portuguese Atomic Energy Commission of Lisbon, Portugal.

8. A 1,000 tkw pool type reactor being built by American Machine & Foundry Co. for Hamilton College of McMaster University in Hamilton, Ontario, Canada.

Continued operation: Reactors completed overseas by U.S. firms in previous years which continued operation during 1958 are the following:

1. A 5,000 tkw pool type reactor built by Babcock & Wilcox Co. for the University of Sao Paulo in Brazil.

2. A 1,000 tkw pool type reactor built by American Machine & Foundry Co. in Munich, West Germany.

3. A 1,000 tkw pool type reactor built by Oak Ridge National Laboratory and sold by the U.S. government to Reaktor A.G. at Wuerenlingen, Switzerland.

Plans announced: Plans were announced during the year for the construction of a research reactor in the Philippines with U.S. governmental assistance.

TRAINING AND SMALL RESEARCH REACTORS

This section is concerned with reactors of less than 50 thermal kilowatts in power.

Newly completed: The following small reactors were completed and/or delivered during the year:

Nine reactors built by Aerojet-General Nucleonics for the following purchasers: University of Akron, University of Basel (Switzerland), University of Delaware, University of Geneva (Switzerland), University of Oklahoma, Oregon State College, University of Palermo (Sicily), Rice Institute, University of Utah.

Three reactors built by General Dynamics Corp. on its own behalf and for the following purchasers: University of Arizona and University of Lovanium (Leopoldville, Belgian Congo).

Two reactors built by North American Aviation, Inc., one for its own use, and one for Interatom (Duisburg, Germany).

One reactor built by American Radiator & Standard Sanitary Corp. for its own use.

One reactor built by Argonne National Laboratory for the AEC.

One reactor built by Babcock & Wilcox Co. for its own use.

One reactor built by the University of Florida for its own use.

One reactor built by Nuclear Development Corp. of America for its own use.

Began construction: Orders were received and/or construction began during 1958 for the following small research reactors:

Four reactors being built by Aerojet-General Nucleonics.

Three reactors being built by General Dynamics Corp. for the following purchasers: the Austrian Ministry of Education (Vienna, Austria), Comitato Nazionale per le Ricerche Nucleari (Rome, Italy), and the University of Minas Gerais (Belo Horizonte, Brazil).

Three reactors being built by North American Aviation, Inc. for the University of Wyoming, the Polytechnic Institute of Milan, Italy and the Senate of West Berlin, Germany.

One reactor being built by American Radiator & Standard Sanitary Corp. for Iowa State College.

One reactor being built by Cornell University for its own use.

One reactor being built by Curtiss-Wright Corp. for the University of Missouri.

One reactor being built by The National Aeronautics and Space Administration for its own use.

One reactor being built by Nucledyne Corp. for North Carolina State College.

Continued operation: Small research and training reactors completed in previous years which continued in operation in 1958 are the following:

Nine reactors built by Aerojet-General Nucleonics, one on its own behalf and the others for the following purchasers: Argonne National Laboratory, University of California, Catholic University of America, Colorado State University, National Naval Medical Center, Oklahoma State University, Texas A&M College, and U.S. Naval Post Graduate School.

Six reactors built by North American Aviation, Inc., three of which are on behalf of the AEC, one for the Danish Atomic Energy Commission, one for the Japan Atomic Energy Research Institute, and one for Farbwerke Hoechst, AG of Frankfurt, West Germany.

Four reactors built by the Du Pont Co. on behalf of the AEC.

Three reactors built by General Electric Co., one of which is for its own use and two of which were built on behalf of the AEC.

One reactor built by American Machine & Foundry Co. for the University of Delft (the Netherlands).

One reactor built by Argonne National Laboratory for its own use.

One reactor built by General Dynamics Corp. (through its Canadair subsidiary) for Atomic Energy of Canada, Ltd.

One reactor built by North Carolina State College for its own use.

Plans announced: During the year plans were announced for the following small research and training reactors:

Thirty reactors for which Aerojet-General Nucleonics applied for or received AEC construction permits.

Four reactors to be built by General Dynamics Corp.—one for Korea, one for Viet Nam and two for Japan.

Two reactors to be built by General Electric Co. for Stanford University and Worcester (Mass.) Polytechnical Institute.

One reactor to be built by Bendix Aviation Corp. for the University of Kansas.

One reactor to be built by Argonne National Laboratory at Idaho Falls, Idaho.

Plans canceled: The University of California at Los Angeles canceled its plans for a small medical reactor to be built by North American Aviation, Inc.

Dismantled: North American Aviation, Inc. dismantled a small homogeneous research reactor.

CRITICAL EXPERIMENT FACILITIES

Newly completed: During the year 13 new critical facilities for testing the design and performance of reactor cores were placed in operation by Babcock & Wilcox Co. (two facilities), Brookhaven National Laboratory, General Electric Co. (three facilities), Lockheed Aircraft Corp., Martin Co., National Aeronautics and Space Administration, Oak Ridge National Laboratory (two facilities), Pratt & Whitney Aircraft, and Westinghouse Electric Corp.

Began construction: Construction began during 1958 on two critical facilities to be operated by Allis-Chalmers Manufacturing Co. and Westinghouse Electric Corp.

Continued operation: Thirty-six critical facilities completed in earlier years continued to be operated in 1958 by the following organizations:

Alco Products, Inc., Argonne National Laboratory (four facilities), Babcock & Wilcox Co., Battelle Memorial Institute, Brookhaven National Laboratory, Combustion Engineering, Inc. (two facilities), General Dynamics Corp., General Electric Co. (10 facilities), Martin Co., Nuclear Development Corp. of America, Oak Ridge National Laboratory (two facilities), Phillips Petroleum Co. (two facilities), Westinghouse Electric Corp. (nine facilities).

Plans announced: Plans were announced by Argonne National Laboratory for three critical facilities.

NON-REACTOR ACTIVITIES

URANIUM MILLS

Newly completed: During the year 1958 the following 11 companies put uranium mills into operation at the locations and with the capacities cited below:

1. Dawn Mining Co. at Ford, Wash. (400 tons per day)
2. Gunnison Mining Co. at Gunnison, Colo. (200 tons per day)
3. Homestake-New Mexico Partners at Grants, N.M. (750 tons per day)
4. Kermac Nuclear Fuels Corp. at Grants, N.M. (3,630 tons per day)
5. Lucky Mc Uranium Corp. at Fremont Co., Wyo. (750 tons per day)
6. Texas-Zinc Minerals Corp. at Mexican Hat, Utah (775 tons per day)
7. Trace Elements Corp. at Maybell, Colo. (300 tons per day)
8. Western Nuclear Corp. at Split Rock, Wyo. (400 tons per day)
9. Fremont Minerals, Inc. at Riverton, Wyo. (500 tons per day)
10. Homestake-Sapin Partners at Grants, N.M. (1,500 tons per day)
11. Lakeview Mining Co. at Lakeview, Ore. (210 tons per day)

Continued operations: The following 12 mills previously completed continued in operation during 1958:

1. Anaconda Co. at Grants, N.M (3,000 tons per day)
2. Climax Uranium Co. at Grand Junction, Colo. (350 tons per day)
3. Kerr-McGee Oil Industries, Inc. at Shiprock, N.M. (500 tons per day)
4. Mines Development Co. at Edgemont, S.D. (300 tons per day)
5. Phillips Petroleum Co. at Grants, N.M. (1,725 tons per day)
6. Rare Metals Corp. of America at Tuba City, Ariz. (250 tons per day)
7. Union Carbide Nuclear Co. at Rifle, Colo. (1,000 tons per day)
8. Union Carbide Nuclear Co. at Uravan, Colo. (1,100 tons per day)
9. Uranium Reduction Co. at Moab, Utah (1,500 tons per day)
10. Vanadium Corp. of America at Durango, Colo. (430 tons per day)
11. Vitro Corp. of America at Salt Lake City, Utah (550 tons per day)
12. AEC at Monticello, Utah (600 tons per day)

Plans announced: Under negotiation with AEC as of the end of 1958 were contracts for the following six new mills:

1. Apex Mining Co., in Nevada (300 tons per day)
2. Cotter Corp. in Colorado (200 tons per day)
3. Federal Uranium Corp., in Wyoming (520 tons per day)
4. International Resources Corp., in the Dakotas (600 tons per day)
5. Union Carbide Nuclear Corp., in Wyoming (400 tons per day)

g. Union Carbide Nuclear Co. and Columbia-Southern Chemical Corp., in Texas (600 tons per day)

The AEC also approved plans to expand the Western Nuclear Corp. mill at Split Rock, Wyo. to 845 tons per day; the Lucky Mc Uranium Corp. mill in Fremont County, Wyo. to 1,000 tons per day, and the Fremont Minerals, Inc. mill at Riverton, Wyo. to 725 tons per day.

Totals: U.S. uranium mills in operation or under construction as of the end of 1958 had a total milling capacity of approximately 21,000 tons of ore per day, and a total cost of approximately $135 million. Total U.S. reserves of measured, indicated and inferred uranium ore were estimated at 83 million tons, averaging about 0.28% U_3O_8. Total U.S. production as of the end of 1958 was at the rate of more than 15,000 tons of U_3O_8 per year.

RADIOISOTOPE APPLICATIONS

Types of applications: Of the new radioisotope applications in 1958, 83 represented organizations which started using materials for gaging applications – 71 for thickness or density gaging and 12 for other types of gaging. 53 organizations started using radioactive materials for radiographic inspection, 36 obtained AEC general authorizations to use radioactive materials for any research and development application, and 30 obtained material for processing into products for resale.

Types of firms: Of the 186 industrial firms which started using radioactive materials for the first time in any form during 1958, firms engaged in food or agriculture increased by 41.6% over 1957 totals, firms engaged in research, development and testing increased by 27.2% over 1957 totals, firms engaged in aircraft increased by 25% over 1957 totals, and firms engaged in machinery increased by 21.3% over 1957 totals. Other increases occured in chemicals (up 18.7%), in electrical equipment, electronics and instrumentation (up 17.3%), and in the paper-plastics industry (up 13.8%).

Location of firms: Among the eight states having more than 100 firms using radioactive material, California increased by 39 (up 19.9% over 1957 totals) to become the leading state in number of industrial radioisotope users. New York totals increased by 24 (up 12.1%) and dropped to second place. The third state, Pennsylvania, increased by 21 (up 13.4%); the fourth state, New Jersey, increased by 11 (up 7.5%); the fifth state, Illinois, increased by 19 (up 14.6%); the sixth state, Massachusetts, increased by 13 (up 10.2%); the seventh state, Ohio, increased by 8 (up 6.6%) and the eighth state, Texas, increased by 11 (up 10.0%).

States with more than 50 (but less than 100) industrial firms using radioisotopes during 1958 were Connecticut, Indiana, Michigan and Wisconsin.

Application trends: Additional statistical data on the industrial utilization of radioactive isotopes in tabular and graphic form are included at the end of this summary. Increases were due primarily to the increased utilization of gages for the measurement of specific gravity of fluids (tomato paste, liquid oxygen, liquid soaps, chemicals, starch solutions, and slurries of fibers) within pipes in the food, missiles, soap, chemical, textile and home products industries. Of interest is the increase in gaging in the food industry in California. Research and development by industry utilizing radioactive materials for unspecified general applications also showed a continued large increase. The aircraft industry gain was due primarily to the increased use of luminescent markers containing AEC-licensed radioactive material.

High-level gamma facilities: As of January 1, 1959 there were 65 institutions licensed by the AEC as high level gamma facilities each using at least 100 curies of radioactive cobalt-60. Of the total number of 81 such sources used by these institutions, 10 contain more than 15,000 curies of cobalt-60, 3 contain from 10,000 to 14,999 curies, 3 contain from 5,000 to 9,999 curies, 41 contain from 1,000 to 4,999 curies, 12 contain from 500 to 999 curies and 12 contain from 100 to 499 curies. The sources and facilities in order of the source size are: first – 65,000 curies at Inland Testing Laboratories, Illinois; second – 50,000 curies at Picker X-Ray Corp., Ohio; third – 30,000 curies at General Electric Co., New York; fourth – 28,000 curies at Dow Chemical Co., Michigan; fifth – 25,000 curies at Texas Co., New York; sixth – 25,000 curies at Admiral Corp., Illinois; seventh – 21,589 curies at Wright-Patterson Air Force Base, Ohio; eighth – 20,000 curies at Southwest Research Institute, Texas; ninth – 20,000 curies at Curtiss-Wright Corp., Pennsylvania; and tenth – 15,000 curies at Nuclear Systems (Budd Co.), Pennsylvania.

The quantity of cobalt-60 in these facilities totals 431,000 curies or roughly equivalent to 185 times the entire estimated world quantity of refined radium (1,500 grams) in terms of irradiation strength.

Radioisotope sources of radiation: Five industrial organizations and 13 universities and medical institutions received AEC licenses during 1958 authorizing the purchase of radioactive cobalt sources of radiation in excess of 100 curies each. The new industrial licensees and the number of curies authorized for each are Aerojet-General Corp. (10,000 curies), Gamma Industries (500 curies), General Electric Co. (30,000 curies), Lockheed Aircraft Corp. (2,000 curies), and Picker X-Ray Corp. (50,000 curies).

Two industrial organizations were licensed during 1958 to receive quantities greater than 100 curies each of radioisotopes other than cobalt – Gamma Industries for 200 curies of cesium-137 and 1,000 curies of iridium-192, and Picker X-Ray for 3,000 curies of iridium-192.

Food irradiator contract: Curtiss-Wright Corp. was awarded an AEC contract in 1958 to design, construct and test operate a two million curie cobalt-60 High Intensity Food Irradiator at the U.S. Army Ionizing Radiation Center at Sharpe General Depot in Lathrop, Cal., scheduled for 1960 completion. The company was selected to build the $2 million facility from a total of 15 proposals received by AEC.

Industrial radiation application studies: The "CEM Group" composed of Emerson Radio & Phonograph Corp., General Aniline & Film Corp. and Revere Copper & Brass, Inc. initiated in 1958 on behalf of the AEC a technical and management study of industrial applications of high-level radiation. The technical aspects of the study are being carried out by Arthur D. Little, Inc. on a subcontract basis.

General Electric Co. and Arthur D. Little, Inc. initiated a study in 1958 on behalf of the AEC designed "(1) to estimate the growth pattern of the markets for irradiation sources of all types and (2) to determine the role fission products could play in the development of these markets."

North Carolina State College and a group of textile companies began a three-year, $275,000 study largely financed by the AEC, of the application of nuclear energy to textile and fabrics manufacturing.

Auxiliary power for space uses: The AEC reported during the year that it and the Defense Department are supporting the development of a number of nuclear devices for the production of power for use in satellites and space vehicles, the general project being known as

SNAP (for Systems for Nuclear Auxiliary Power). The devices under study are the following:

SNAP-1, which uses fission product radioisotopes as a heat source to operate a generator. Martin Co. is the prime contractor, with Thompson Ramo Wooldridge, Inc. as a subcontractor for the generating machinery.

SNAP-2, which uses a nuclear reactor as a heat source to operate a generator. North American Aviation, Inc. is the prime contractor, and Thompson Ramo Wooldridge is the machinery subcontractor.

SNAP-3, which uses radioactive polonium or cerium as a heat source, with direct thermoelectric conversion of the heat into electricity. Martin Co. is the prime development contractor.

OTHER INDUSTRIAL ACTIVITIES

The following noteworthy industrial atomic energy activities were begun or continued during 1958.

Particle accelerator sales: Of the four U.S. companies manufacturing particle accelerator machines commercially, High Voltage Engineering Corp. delivered 35 machines valued at $5.75 million during 1958, Applied Radiation Corp. sold four machines valued at $850,000, and no figures were reported by General Electric Co. and Varian Associates.

The High Voltage machines were delivered to the following organizations: Aberdeen Proving Grounds, American Chain & Cable Co., American Cyanamid Co., A.B. Atomenergie (Sweden), Brookhaven National Laboratory, Canadian Department of Defense Production, Case Institute of Technology, Chalk River Laboratories (Atomic Energy of Canada Ltd.), Ethicon, Inc., Florida State University, Georgia Institute of Technology, Johns Hopkins University, Mellon Institute, Memorial Hospital (New York City), National Taing Hua University (Formosa), Oak Ridge National Laboratory, Pratt & Whitney (United Aircraft), Princeton University, Reading University (England), Sandia Corp., Sumito Nuclear Research Group (Japan), Syracuse University, Taka Institute (India), Technical Institute of Karlsruhe (Germany), Texas Co., Thiokol Chemical Corp., University of Algiers (Africa), University of California, University of Connecticut, University of Frieburg (Germany), University of Hamburg (Germany), University of Maryland, University of North Carolina, University of Texas, and University of Utrecht (Germany).

Applied Radiation delivered machines to Argonne National Laboratory, General Dynamics Corp., Phillips Petroleum Co. and Texas Co. At the end of 1958 the company also had five additional machines valued at a total of $3.2 million under construction for Los Alamos Scientific Laboratory, Massachusetts Institute of Technology-Harvard University, Rensselaer Polytechnic Institute, University of California and Yale University.

Nuclear fuel preparation: Two companies – American Lava Co. and Davison Chemical Co. – completed new facilities for the chemical preparation and/or fabrication of uranium and thorium nuclear fuel during 1958.

The chemical preparation and/or fabrication of uranium fuel also continued to be performed by the following 21 companies in previously existing facilities: Aerojet-General Corp., Babcock & Wilcox Co., Clevite Corp., Combustion Engineering, Inc., Engelhard Industries, Inc., General Dynamics Corp., General Electric Co., Gulton Industries, Inc., M&C Nuclear, Inc., Mallinckrodt Chemical Works, Martin Co., National Lead Co., North American Aviation, Inc., Norton Co., Nuclear Development Corp. of America, Nuclear Materials & Equipment Corp., Nuclear Metals, Inc., S.W. Shattuck Chemical Corp., Spencer Chemical Co., Sylvania-Corning Nuclear Corp. and Westinghouse Electric Corp.

Thorium metal and/or compounds for nuclear fuel use were produced during the year by the following nine companies: Heavy Minerals Co., Horizons, Inc., Lindsay Chemical Co., Maywood Chemical Co., National Research Corp., Nuclear Materials & Equipment Corp., Rare Earths, Inc., Sylvania-Corning Nuclear Co. and Vitro Corp. of America.

Uranium scrap recovery: Davison Chemical Co. and Nuclear Materials & Equipment Corp. were newly licensed by the AEC to recover unirradiated enriched uranium scrap. Baker & Co. (division of Engelhard Industries) continued scrap recovery activities under a previous license.

Waste disposal: The following four companies were newly licensed by the AEC during 1958 to provide radioactive waste disposal services: Coastwise Marine Disposal Co., Industrial Waste Disposal Corp., New England Tank Cleaning Co. and Nuclear-Chem Disposal Corp.

The following 11 previously licensed companies continued to provide waste disposal services: American Mail Lines, Atomic Energy Waste Disposal Service, California Salvage Co., Crossroads Marine Disposal & Salvage Co., Isotope Specialities, Inc., Nuclear Consultants, Inc., Nuclear Engineering Co., Inc., Radiological Service Co., Inc., Reed-Curtis Nuclear Industries, Inc., Walker Trucking Co. and Woodbury Clay Co.

Uranium refining: Allied Chemical & Dye Corp. continued the construction of a plant for the refining of uranium and production of uranium hexafluoride. Mallinckrodt Chemical Works and National Lead Co. continued the operation of AEC plants located respectively at Weldon Spring, Mo. and Fernald, Ohio.

Uranium enrichment: Two companies continued the operation of plants for the enrichment of uranium in the U-235 isotope on behalf of the AEC – Union Carbide Nuclear Co. (which operates plants at Oak Ridge, Tenn. and Paducah, Ky.) and Goodyear Tire & Rubber Co. (which operates a plant at Portsmouth, Ohio).

Heavy water production: E.I. du Pont de Nemours & Co. continued the operation of a heavy water production plant on behalf of the AEC at Aiken, S.C.

Beryllium production: Beryllium Corp. and Brush Beryllium Co. continued the production of beryllium under AEC contracts and for commercial sale.

Zirconium production: Carborundum Metals Co., Columbia-National Corp. and Mallory-Sharon Metals Co. continued the production of zirconium under AEC contract and for commercial sale, and Wah Chang Corp. continued operation of a government-owned zirconium plant.

Controlled thermonuclear research: Five companies continued substantial research programs in the field of controlled thermonuclear research: Allis-Chalmers Manufacturing Co. and Radio Corp. of America (which are constructing the Model C Stellarator on behalf of Princeton University and the AEC), General Dynamics Corp. (which is conducting a four-year research program jointly with the Texas Atomic Energy Research Foundation, a group of 11 utilities), General Electric Co. (which is conducting research on its own behalf), and Westinghouse Electric Corp. (which is conducting research for the AEC).

GOVERNMENTAL ACTIONS

Access permits: Approximately 185 permits for access to classified information were issued by AEC during 1958 – many of them to industrial firms – bringing the total issued to date to more than 1,400.

Bilateral agreements: New bilateral agreements making possible power reactor sales to other nations by U.S. industrial firms were signed during the year between the U.S. and three other nations – Cuba, Japan and Venezuela. At the end of 1958 the U.S. had entered into or initialed research agreements with 27 nations (plus West Berlin) and comprehensive power and research agreements with 17 nations.

The power agreements (which also cover research materials and equipment) are with the following countries: Australia, Belgium, Brazil, Canada, Cuba, France, Germany, Italy, Japan, Netherlands, Norway, Peru, Spain, Switzerland, United Kingdom, Union of South Africa and Venezuela.

Research agreements are with the following countries: Argentina, Austria, Chile, China, Colombia, Costa Rica, Denmark, Dominican Republic, Ecuador, Greece, Guatemala, Iraq, Iran, Ireland, Israel, Korea, Lebanon, New Zealand, Nicaragua, Pakistan, Philippines, Portugal, Sweden, Switzerland, Thailand, Turkey and Uruguay.

State activities: During the year Kentucky established an office of nuclear information with a director serving as state coordinator of atomic energy, bringing the total number of states having an individual assigned the task of coordinating atomic energy at the state level to twelve (Arkansas, Connecticut, Florida, Georgia, Kentucky, Maine, Massachusetts, New Hampshire, Ohio, Rhode Island, Tennessee and Washington).

Two states, Michigan and Minnesota, adopted radiation codes in addition to the following six states which had previously adopted codes: California, Connecticut, Massachusetts, New York (with two state-level codes), Pennsylvania and Texas. The City of New York adopted a comprehensive radiation ordinance.

At year's end, 16 states required registration of radiation sources either as a result of code requirements or as a result of statutory legislation (Alaska, Colorado, Connecticut, Delaware, Illinois, Kansas, Massachusetts, Michigan, Minnesota, New Jersey, New York, North Dakota, Pennsylvania, South Dakota, Texas and Wyoming.)

During the year, six states (Kentucky, Mississippi, North Carolina, Oklahoma, Oregon and Washington) established study groups or commissions serving as advisory committees to the governor, the legislature, or a state agency on atomic energy or radiation controls, bringing to 30 the total number of states to have done so.

In 1958, the Southern Governors' Conference adopted a resolution initiating action on an atomic energy interstate compact in the South and continuing the Regional Advisory Council on Nuclear Energy.

TYPES OF RADIOISOTOPE APPLICATIONS MOST FREQUENTLY USED BY INDUSTRIAL ORGANIZATIONS

TYPE OF APPLICATION	NUMBER OF ORGANIZATIONS*		
	1946–1957	1958	1946–1958
GAGING	510	83	593
THICKNESS & DENSITY	354	71	425
OTHER	168	12	180
RADIOGRAPHIC INSPECTION	432	53	485
RADIATION EFFECTS	97	8	105
PROCESS & RESALE OF RADIOISOTOPES	69	30	99
LUMINESCENT MATERIALS & PHOSPHORS	68	16	84
GENERAL AUTHORIZATIONS (Any Research & Development)	45	36	81
IONIZATION SOURCES	52	12	64
WEAR STUDIES	41	8	49
ACTIVATION ANALYSES	32	2	34
LEAK DETECTION	29	5	34
STUDIES OF CATALYSTS & CATALYTIC REACTIONS	17	2	19
RADIOACTIVE BATTERY	16	2	18
STUDIES OF DETERGENTS	14	3	17
AEC CONTRACT RESEARCH	15	0	15

*Single organizations employing radioisotopes in more than one of the listed applications are represented by multiple numbers. (AIF-1958)

TYPES OF INDUSTRIAL ORGANIZATIONS

TYPES OF INDUSTRIAL ORGANIZATIONS USING RADIOISOTOPES

TYPE OF ORGANIZATION	NUMBER OF ORGANIZATIONS		
	1946–1957	1958	1946–1958
RESEARCH – DEVELOPMENT – TESTING	163	46	209
ELECTRICAL EQUIPMENT – ELECTRONICS – INSTRUMENTATION	134	23	157
METAL WORKING	133	11	144
PAPER – PLASTICS	101	14	115
CHEMICALS	80	15	95
MANUFACTURING (Other Than Indicated)	76	5	81
PETROLEUM – ALLIED	74	6	80
MACHINERY	61	13	74
FOOD – AGRICULTURE	36	15	51
RUBBER	43	2	45
PIPING – VALVES – TANKS	37	2	39
AIRCRAFT	24	6	30
BUILDING MATERIALS	27	1	28
PHARMACEUTICALS – MEDICAL SUPPLIES	26	3	29
ENGINEERING – CONSTRUCTION	24	4	28
TEXTILES – LEATHER	21	3	24
MINING	18	1	19
COMMUNICATIONS	14	–	14
AUTOMOTIVE	10	1	11
GLASS – TILE – CONCRETE	10	2	12
RAILROADS – ALLIED	10	2	12
UTILITIES	10	1	11
OPTICAL – PHOTOGRAPHY	9	–	9
PRINTING – PUBLISHING	8	1	9
MARINE	7	–	7
ABRASIVES	7	–	7
TOBACCO	6	–	6
OTHER	12	2	14
UNIDENTIFIED (Not Listed in Standard Industrial Indices)	135	7	142
TOTAL	1316	186	1502

(AIF-1958)

GEOGRAPHICAL DISTRIBUTION OF INDUSTRIAL ORGANIZATIONS USING RADIOISOTOPES *

STATE	NUMBER OF INSTALLATIONS			STATE	NUMBER OF INSTALLATIONS		
	1946–1957	1958	1946–1958		1946–1957	1958	1946–1958
ALABAMA	24	2	26	MONTANA	0	1	1
ALASKA	0	0	0	NEBRASKA	2	0	2
ARIZONA	4	0	4	NEVADA	3	0	3
ARKANSAS	9	0	9	NEW HAMPSHIRE	5	3	8
CALIFORNIA	196	39	235	NEW JERSEY	147	11	158
COLORADO	17	6	23	NEW MEXICO	6	1	7
CONNECTICUT	69	3	72	NEW YORK	198	24	222
DELAWARE	13	2	15	NORTH CAROLINA	15	0	15
DIST. OF COLUMBIA	7	1	8	NORTH DAKOTA	0	0	0
FLORIDA	11	2	13	OHIO	122	8	130
GEORGIA	12	2	14	OKLAHOMA	35	4	39
HAWAII	2	1	3	OREGON	5	1	6
IDAHO	5	0	5	PENNSYLVANIA	157	21	178
ILLINOIS	130	19	149	RHODE ISLAND	19	0	19
INDIANA	43	8	51	SOUTH CAROLINA	4	2	6
IOWA	11	1	12	SOUTH DAKOTA	0	0	0
KANSAS	8	2	10	TENNESSEE	19	5	24
KENTUCKY	14	2	16	TEXAS	108	11	119
LOUISIANA	23	5	28	UTAH	8	1	9
MAINE	18	0	18	VERMONT	2	0	2
MARYLAND	32	4	36	VIRGINIA	26	5	31
MASSACHUSETTS	118	12	130	WASHINGTON	24	4	28
MICHIGAN	48	4	52	WEST VIRGINIA	10	0	10
MINNESOTA	17	3	20	WISCONSIN	46	4	50
MISSISSIPPI	8	0	8	WYOMING	1	1	2
MISSOURI	19	7	26	TOTAL	1820	233	2053

*Single organizations located in different cities and states are represented by multiple numbers. (AIF-1958)

APPENDIX 6

Survey of Initial Fuel Costs of Large U.S. Nuclear Power Stations

December, 1958

A Report of the Technical Appraisal Task Force on Nuclear Power to the Board of Directors of the Edison Electric Institute

Preface

A primary purpose of the Technical Appraisal Task Force on Nuclear Power of the Edison Electric Institute is to make an objective review of the present status and future prospects for the production of electric power from nuclear fuels. The first publication of the Task Force, *Status and Prospects of Nuclear Power—An Interim Survey*, issued in 1958, is such a general review.

Having set forth a brief summary on the present state of the art in nuclear power development in that publication, the Task Force felt it appropriate to proceed to more detailed examination of the indicated power costs of the large nuclear power stations now operating or under construction in this country. This report on fuel cycle costs, prepared with the assistance of Pickard-Warren-Lowe Associates, includes projections of initial fuel costs for the first four large U. S. commercial stations and the AEC station at Shippingport.

The Task Force wishes to point out that the cost figures used in this report are engineering estimates. Since there is no operating experience on which to base these estimates, there is necessarily a number of uncertainties involved. These uncertainties, which are analyzed in the report, should be taken into consideration in interpreting the conclusions of the report. The number and magnitude of uncertainties in cost data on nuclear fuels should be substantially reduced when actual operating data covering several years are available.

The report is divided into three parts. Section I and Table II, with its notes, summarize the findings of the report and background information concerning estimates of initial fuel costs for the first five large U. S. nuclear power stations. Section II is an analysis of the elements of nuclear fuel cost and the factors affecting them. The Appendix describes assumptions and methods used in the fuel cost analyses.

SECTION I — SUMMARY AND CONCLUSIONS

Now that the technical feasibility of large-scale generation of electric power from nuclear energy has been demonstrated, the pursuit of lower power costs becomes the primary task in nuclear power development. This is at least a twofold effort involving (1) cost reduction through further improvement in technically proven reactors, such as the water-cooled types, and (2) exploration of other reactor concepts with the hope of realizing possible inherent cost advantages.

The effort to improve the more fully developed types of power reactors must be based upon all pertinent data available. Pertinent data include not only technical design and performance, but economic factors as well. While it is apparent that present nuclear plant costs may be reduced in the future, it is quite likely that for some time nuclear plants will have capital costs in excess of those for equivalent conventional plants. Therefore, nuclear fuel costs must be substantially lower than fossil fuel costs if nuclear energy is to be competitive in the United States within the next five to ten years.

This report is directed to presenting and analyzing nuclear fuel costs, in the belief that such information provides necessary background for guiding future efforts to achieve lower costs as well as to appraise the potentialities of nuclear power.

In the absence of commercial nuclear power experience, the most realistic fuel cycle cost estimates are believed to be those related to the initial operation of the first large commercial plants under construction in this country.* Therefore this study is confined to the large water-cooled plants (Indian Point, Rowe and Dresden stations), the large fast breeder plant (Enrico Fermi station) and the first large prototype water-cooled nuclear power station, the Shippingport plant.

* Consolidated Edison's 255 emw (152 emw nuclear) pressurized-water Indian Point station; Yankee Atomic Electric's 134 net emw pressurized-water Rowe station; Commonwealth Edison's 180 net emw boiling-water Dresden station; Power Reactor Development Company's 100 net emw fast breeder Enrico Fermi station; and AEC's 60 net emw pressurized-water Shippingport station, operated by Duquesne Light Company.

The specific purposes of this report concerning fuel costs are to (1) present and interpret fuel cost estimates on a consistent basis for the initial three years of rated operation of the first large U. S. commercial nuclear power stations now under construction, (2) assess the degree of uncertainty in these cost estimates and (3) analyze the elements of fuel cost to show their relative importance.

CONCLUSIONS

1. The successful performance of a nuclear power reactor depends as much on a satisfactory fuel as on any other single factor. Poor fuel performance can raise total generation costs by several mills per electric kilowatt-hour (mills per ekwhr), while good performance can have the opposite effect.

2. At present three out of the first four large U. S. commercial nuclear power reactors—Indian Point, Rowe and Dresden—will use uranium-oxide fuel, in one case mixed with thorium oxide, anticipating that in full-scale use uranium-oxide fuel will prove as feasible and economic as tests and limited operations to date indicate.

3. Nominal fuel cost estimates range from 3.5 to 7 mills/ekwhr for the first three years after rated operation and anticipated plant availability are achieved in the large commercial water-cooled nuclear power plants (assuming plutonium is worth $30 per gram). When uncertainties are considered, the lowest probable costs range from 2 to 4 mills/ekwhr, and the highest from 5 to 13 mills/ekwhr for the water-cooled plants. Within these ranges the approximate effect of assuming $12 instead of $30/gram for plutonium is an increase of 1 to 2 mills/ekwhr in fuel cost. Fuel cost with $30/gram credit for plutonium in the more experimental, high-temperature, sodium-cooled fast breeder, the Enrico Fermi station, is approximately 10 mills/ekwhr for initial operation, with the lowest probable cost being about 5 and the highest about 15 mills/ekwhr.

4. The Shippingport station first-core fuel costs have been estimated in a manner consistent with that for the large commercial plants. The esti-

mate is about 33 mills/ekwhr, assuming the first seed elements operate for 3000 full-power hours, and a little more than 20 mills/ekwhr if 6000 full-power-hour seed life is achieved, which initial operation now indicates should easily be possible.

5. With the exception of the Shippingport station, which is now in operation, the other stations dealt with in this report will not be in operation before the early 1960's. Thus, because of lack of operating experience, the fuel cost estimates are to a large degree uncertain. These uncertainties are definable and have been approximated. For slightly enriched uranium-oxide fuel, it is concluded that there is about a 90 percent chance that actual costs will be within the range of about +25 to −40 percent of current estimates for the large-station fuel cores after rated operation and anticipated plant availability are achieved. Uncertainties in the initial costs of thoria-urania and metallic-alloy fuels (in the Indian Point and Enrico Fermi plants, respectively) are higher.

6. While nearly all of the major elements of fuel cost are subject to uncertainties, the factor having the largest influence on total uncertainty is the potential variation in the burnup—the amount of energy produced from a given weight of fuel before it has to be discharged. Nominal energy production ranging from 7000 to 11,000 thermal megawatt days per short ton of fissionable and fertile material (tmwd/t) is planned for enriched uranium-oxide and metallic-alloy fuels and around 15,000 tmwd/t for thoria-urania fuels. Uncertainties in these estimates are high—in the order of +80 to −40 percent in the most uncertain case.

7. The largest single component of total fuel cost is the fuel-element fabrication cost, which is estimated to range from 35 percent to more than 70 percent of the total for the large commercial stations. Next in importance are the net fuel-material cost and spent fuel recovery cost.

8. The accumulation of experience during the next several years will undoubtedly reduce uncertainties now applicable to the fuel-cost estimates in this report. On the other hand, the values of plutonium and enriched uranium on which the cost estimates are based are established by government regulations. The possibility that these regulations may change was not considered in estimating uncertainties, but the effect of variations in plutonium value has been considered separately.

9. Continuing reactor development, as well as the accumulation of operating data, will bring about reductions in many if not all elements of fuel cost for both the first and subsequent plants. Hence, actual fuel costs experienced after the first three years of rated operation may be appreciably below the cost estimates in this report.

The largest reductions will probably result from improvements in the more important factors affecting total fuel costs, such as burnup and fuel fabrication costs. Early operating experience, if coupled with carefully planned operational testing and analyses, should prove particularly effective in lowering these as well as other fuel-cost elements.

10. The high relative cost of fuel fabrication warrants special attention, particularly in view of the marked difference indicated between cost experience reported for Shippingport and cost contemplated by other project estimates. General analyses of this report indicate that these marked differences can be rationalized.

BACKGROUND OF THE REPORT

A number of small experimental nuclear power reactors have gone into operation and large U. S. nuclear central stations involving an investment of more than $300 million are under construction. During the lifetime of these plants hundreds of millions of dollars more will be spent for nuclear fuel and fuel processing for them. Meaningful experience with some of the most important elements of their fuel costs is still very limited.

Present design and construction programs include either prototype or full-scale power plants of many of the promising types of nuclear reactors. Nevertheless, since the development of reactors is still in an early stage, the principal effort in designing and building these reactors has been aimed at making equipment work and finding fuel elements which will meet minimum operating requirements. The selective process of finding the best and most economic combinations of fuels, reactor types and operating methods has just begun.

The reactor fuel cost estimates in this report have been developed during a period when nuclear power technology has been evolving rapidly. Consequently, almost all fuel cost data are subject to uncertainties characteristic of developmental work, rather than proven commercial experience.

The fuel costs have been calculated on the basis of the best data available from reactor designers and operators, adapted to a consistent set of ground rules.

TYPES OF NUCLEAR FUELS

There are many possible combinations of the three principal fissionable materials: uranium 235, plutonium and uranium 233; and the two fertile materials — uranium 238 and thorium — which may be used as fuel in power reactors.

Ultimately, the basic fuel materials cost of various fuel cycles and associated reactor types — such as the plutonium–uranium cycle, the thermal

TABLE I — SUMMARY OF NUCLEAR FUELS FOR U. S. POWER REACTORS
(For Initial Operation)

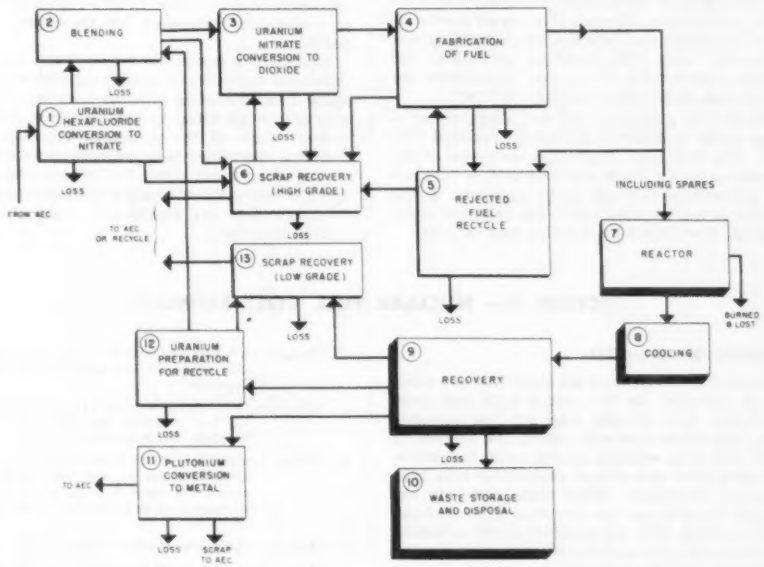
Station—Owner	Nuclear Thermal Capacity (tmw)	Net Station Efficiency (%)	Net Electric Capacity from Nuclear Heat (emw)	Approximate Initial Core Content (kg U)	(kg Th)	(kg U-235)	Average Initial Enrichment (% U-235 in fuel)	Average Specific Power (tkw/kg U & Th)	Fuel Diameter and Form	Fuel Clad	Fuel Structure	Average Fuel Residence[1] (years)
Shippingport—AEC–Duquesne Light Co.[2]												
Blanket	130	—	—	12,900	—	92	0.7	10	0.36-in., UO_2 pellets	Zircaloy 2 tubes	Zircaloy 2	
Seed	100	—	—	80	—	75	93.0	1,250	7% U-Zr alloy plates	Zircaloy 2 plates	Zircaloy 2	
Total	230	26	60									
Enrico Fermi—Power Reactor Development Co.												
Core	250	—	—	1,800	—	485	27.0	138.0	0.158-in. pin, U with 10 w/o Mo	Coextruded Zr tubes	Stainless steel	0.3
Blanket	50	—	—	38,720	—	140	0.36	1.3	0.415-in., U rod Na-bonded	Stainless steel tubes	Stainless steel	2.7
Total	300	33	100									
Indian Point — Consolidated Edison Co. of New York, Inc.	585	26	152[3]	950	16,850	885	5.0	33	0.27-in. ThO_2–UO_2 pellets	Stainless steel tubes	Zircaloy 2	2.0
Rowe—Yankee Atomic Electric Co.	482[3]	28	134[4]	21,400	—	642	3.0	22	0.3-in., UO_2 pellets	Stainless steel tubes	Stainless steel	1.3
Dresden — Commonwealth Edison Co.	626	29	180	53,600	—	792	1.5	12	0.5-in., UO_2 pellets	Zircaloy 2 tubes	Zircaloy 2	3.7

[1] Number of years residence in reactor based on 0.7 plant factor.
[2] AEC owns the reactor; Duquesne Light Co. owns the turbogenerator and operates the station.
[3] Total net electric capacity is 255 emw, of which 103 equivalent emw is from an oil-fired superheater and 152 equivalent emw is from the reactor.
[4] The first core is rated at 392 tmw for a net output of 110 emw; however there is a substantial chance this will be exceeded and, consequently, a higher rating has been assumed. This assumption has only a minor effect on fuel cost.

Chart I

TYPICAL FUEL CYCLE

FOR SLIGHTLY ENRICHED UO_2 FUEL CLAD WITH STAINLESS STEEL



breeder using the U-233–thorium cycle or the thermal converter with a high conversion ratio using natural uranium — may determine the relative merits of the different reactor types. However, fuel developers are not primarily concerned at this time with the relative long-range merits of various fuel cycles, but with more immediate, practical considerations of how to increase burnup, reduce fabrication costs and minimize radiation and corrosion damage. These considerations will probably continue to be controlling factors in the choice of fuel cycles for some time.

A number of types of fuel elements have already been successfully developed for use in plutonium production, naval propulsion and test and research reactors. However, these fuels are generally unsatisfactory for commercial power reactors, because they are too expensive or subject to undesirable temperature or burnup limitations.

Table I presents the technical characteristics of fuel now planned for the first four large U. S. commercial nuclear power plants, as well as AEC's Shippingport plant.

With the exception of the seed elements in the Shippingport reactor and the fuel for the Enrico Fermi core, all of the fuels involved are comprised of high-density cylindrical uranium-oxide or uranium-thorium-oxide pellets encased in either zirconium alloy or stainless-steel tubes. The pellets are from ¼ to ½ inch in diameter.

The fuels for the Dresden and Rowe stations and the Shippingport blanket are uranium oxide. Consolidated Edison's Indian Point station will use thorium and highly enriched uranium in the form of mixed oxide pellets. Eventually uranium 233 produced from the thorium may be recycled to take the place of some of the U-235. The first fuel core for the Enrico Fermi fast breeder will be uranium alloyed with 10 weight percent molybdenum in the form of 1/6-inch diameter pins with coextruded zirconium cladding. The use of oxide or other alloys is being considered for subsequent Enrico Fermi cores, and eventually plutonium produced in the reactor may be recycled.

Thus, for water reactors a degree of uniformity and standardization in fuel designs appears to be developing, which should help lower the costs of preparing and reprocessing these fuels.

‘The first core is rated at 392 mw for a net output of 110 emw; however there is a substantial chance this will be exceeded and, consequently, a higher rating has been assumed. This assumption has only a minor effect on fuel cost.

PROCESSING NUCLEAR FUELS

Nuclear fuels differ from conventional fuels in that they are composed of chemically processed and mechanically formed fuel materials which are highly radioactive after use. The supply and treatment of nuclear fuels involve many handling and processing steps. The chemical, mechanical and isotopic composition of the fuel determines the nature and extent of processing required.

Chart I is a typical fuel flow diagram for a large water reactor using slightly enriched UO_2 fuel. The fuel cycle illustrated, only one of the processing cycles which might be used, is based on the assumption that plutonium produced in the reactor is not recycled, while the uranium is recovered, re-enriched by blending and re-used.

In the near future the recovery of spent fuel, the handling of radioactive wastes and similar important radioactive operations will largely be carried out in government-owned facilities. Accordingly, the estimates in this report are based on rates now estimated for these government services.

Since only a few power reactor fuels have been developed sufficiently to justify significant use, not many fuel processing schemes have been considered in enough detail to provide useful cost estimates. Many of the numerous processing and handling operations have not been carried out on a production basis. Only limited manufacturing and processing experience and calculated fuel performance data are available as bases for estimating fuel costs.

SECTION II — NUCLEAR FUEL COST ESTIMATES

ELEMENTS OF FUEL COST

Nuclear fuel cycle costs are comprised of a number of elements. In this report total fuel cycle costs have been divided into net fuel material costs, fuel fabrication costs, spent fuel processing costs, fuel cycle working capital costs, fuel material lease costs and cost of replaceable core controls and structures. When these costs are expressed in mills per net electrical kilowatt-hour (mills/ekwhr), they are designated with a capital M followed by a subscript to identify each specific element of cost. When they are expressed in terms of dollars per kilogram ($/kg) of uranium and/or thorium passing through the reactor, they are designated with a capital C and appropriate subscript.

Fuel cost in mills/ekwhr can be derived for any of the cost elements by dividing the cost per kilogram of fuel by the average amount of electric energy generated per kilogram. Thus, total fuel cost is:

$$M_t \text{ (mills/ekwhr)} = \frac{C_m+C_f+C_p+C_c+C_l+C_r}{EKBX} = \frac{C_t}{2.2\,BX}$$

where: $E = 2.2 \times 10^7$ kilowatt-hours of heat produced per kilogram of atoms fissioned (tkwhr/kg)—equivalent to about 196 million electron volts per fission (mev/f), or 3.4×10^{10} Btu per pound of atoms fissioned (Btu/lb) or 833,000 thermal megawatt days per short ton of fissioned atoms (tmwd/sht).

$K = 10^{-7}$, a factor to convert to consistent units.

B = burnup (the average weight percent of fuel atoms fissioned).

X = net station efficiency (% net ekwhr/tkwhr).

C_m ($/kg) = net fuel material cost (the cost of fissionable or fertile material burned, lost or degraded).

C_f ($/kg) = fuel fabrication cost (the cost of converting fuel material and fabricating it to finished fuel elements).

C_p ($/kg) = spent fuel processing costs (the cost of extracting fertile and fissionable materials from spent fuel elements and converting them to a form suitable for reuse or credit).

C_c ($/kg) = fuel cycle working capital costs.

C_l ($/kg) = fuel material lease cost (the cost of leasing enriched uranium from the AEC).

C_r ($/kg) = cost of replaceable core controls and structures.

C_t ($/kg) $= C_m+C_f+C_p+C_c+C_l+C_r$ = total fuel cost.

The analyses of fuel costs in this report have been developed using these symbols and relationships. A sample fuel cost calculation and detailed definitions are given in the Appendix.

Each of the elements of fuel cost is subject to various degrees of uncertainty. These uncertainties have been analyzed by the methods described in the Appendix and are important in considering nuclear fuel cost estimates, as discussed later.

FUEL COST ESTIMATES

Fuel cost estimates for the initial operation of the first large commercial U. S. nuclear electric power stations described in Table I are given in Table II. These costs are for fuel and reactor designs which are complete or nearing completion. They are based on fuel cost and performance data provided by the fuel designers and station owners and operators directly involved. The estimates have been made on a consistent basis, detailed in

TABLE II—ESTIMATED FUEL COSTS FOR SPECIFIC NUCLEAR POWER PLANTS[1]

Power Station	SHIPPINGPORT			ENRICO FERMI	INDIAN POINT	ROWE	DRESDEN	Principal Assumptions
Type of Project	First large U.S. nuclear power plant			First large fast breeder	Second generation water-cooled power reactors			
Type of Reactor	Pressurized water			Sodium-cooled	Pressurized water	Pressurized water	Boiling water	
Type of Core	First large core with Zr-2 clad (Th, Heavy U)O$_2$ elements[2]			First large Zr-2 clad U alloy core	First large Zr-2 stainless-steel clad. (Th, U)O$_2$ core	First large stainless-steel-clad. UO$_2$ core	Second large core with Zr-2-clad UO$_2$ elements[3]	
Period Covered by Estimate	First core			First three years after rated operation and anticipated plant availability are achieved				
Rated Power, net mwe	60 mwe	60 mwe[4]	Assumed case 90 mwe[5]	100 mwe	255 mwe, 60% from nuclear heat	134 mwe	180 mwe	Plant utilization factor is 0.7.[6a]
	(mills/kwhr)	(mills/kwhr)	(mills/kwhr)	(mills/kwhr)	(mills/kwhr—for nuclear heat only)	(mills/kwhr)	(mills/kwhr)	
Net cost of U or Th fissioned, transformed or lost (M_c)	2.43	2.20	2.20	2.67	2.65	2.00	1.45	Value of uranium is as given in current AEC schedules.
Credit for Pu (M_{rc}) (with Pu at $30/gm)	1.81	1.74	1.74	3.68	none[6b]	2.50	1.97	Value of recovered Pu is $30/gm or $12/gm as noted.
Net fuel material cost ($M_m = M_c - M_{rc}$)	.62	.46	.46	−1.01	2.65	.50	−.52	
Fuel fabrication costs (M_f)	26.47	17.82	17.82	5.42	2.36	3.02	2.20	Fuel fabrication costs are based on manufacturers' estimates for the Dresden, Rowe and Indian Point stations, projections of Point estimates for Enrico Fermi firm contracts for Shipping-port and recorded costs for Shippingport.
Spent fuel processing costs (M_s)	1.04	.71	.71	2.55	.27	.74	.53	Spent fuel processing cost is based on AEC offer to perform this service.
Fuel cycle working capital costs (M_w)[6c]	2.70	2.67	1.78	.40	.46	.42	.74	Annual fuel cycle working capital cost is 9% of first core fabrication cost plus cost of purchased uranium and thorium, if any.
Fuel material lease costs (M_l)	.52	.39	.34	2.46[6d]	1.16	.74[6d]	.40	Annual fuel material lease cost is 4% of the value of leased uranium in fresh fuel.
Cost of replaceable core controls and structures (M_r)[6e]	2.13	.59	.59	.04	.05	.08	.14	
Total (M_t) (with Pu at $30/gm)	33.48	22.64	21.70	9.86[6a]	6.95[6a]	5.00[6a]	3.49[6a]	Costs are based on "1958 dollars."[6a]

TABLE II *(Continued)*—ESTIMATED FUEL COSTS FOR SPECIFIC NUCLEAR POWER PLANTS[1]

Power Station	SHIPPINGPORT			ENRICO FERMI	INDIAN POINT	ROWE	DRESDEN	Principal Assumptions
	(mills/ekwhr)	(mills/ekwhr)	(mills/ekwhr)	(mills/ekwhr)	(mills/ekwhr—for nuclear heat only)	(mills/ekwhr)	(mills/ekwhr)	
Total (M_t) (with Pu at $12/gm)	34.57	23.67	22.74	12.07[3]	6.95[5,3]	6.44[3]	4.67[3]	
Percent approximate uncertainty in M_t (with Pu at $30/gm)				{+50 / −50}	{+80[9] / −25}	{+25[3] / −40}	{+25[3] / −40}	Uncertainties are estimated for 90% confidence level. There is assumed to be no uncertainty in Pu value, fuel rental rate or enriched uranium value. The effect of changes in Pu value are shown in Chart II.
Approximate range of fuel costs based on uncertainties (with Pu at $30/gm)				5-15	5-13[3]	3-6.5	2-4.5	
Number of core changes during period considered[10]				5-17[11]	1-3	1.0-2.5	.5-1.0	
Average burnup, thousands tmwd/short ton and (%)								
Core	140(17%)	268(32%)[4]	268(32%)[4]	9.16(1.1%)[3]	15.2[3](1.8%)	6.8[3](0.8%)	10.0[3](1.2%)	Average burnup is limited by loss of reactivity (to override equilibrium xenon poison at rated operating conditions) or by radiation damage to fuel.
Blanket	2.94(.35%)	4.4(.53%)[4]	4.4(.53%)[4]	.916(0.1%)[3]				

[1] These are estimates for plants not yet in operation except in the case of Shippingport. The estimates are for specific fuel cores and reactors at various stages of design and development. They do not necessarily represent inherent differences in the economics of basic types of fuel cores and reactors.

[2] Blanket elements of Shippingport are Zr-2-clad UO_2. Seed elements are Zr-U alloy. (See Table I.) The first Dresden core is the second large core using Zr-2-clad UO_2 elements.

[3] Enrico Fermi core elements are Zr-clad U-Mo alloy. Blanket elements are stainless steel-clad, depleted metallic uranium rods. (See Table I.)

[4] There is evidence that core and seed burnup could be substantially greater than in the cases shown with resulting fuel costs in the range of 15 to 18 mills/ekwhr.

[5] The first Indian Point core will be ThO_2 and fully enriched UO_2. Therefore, no plutonium is made and there is no credit for plutonium. Credit for the U-233–U-235 mixture in spent fuel is included in M_t.

[6] Actual M_t for Dresden may be in the order of ½ that shown. For Yankee and Indian Point it may be around ⅔ that shown, and for Enrico Fermi somewhat more than that shown. These differences are due to differences in time from payment of prepaid costs to receipt of compensating revenue, variations in the cost of money and changing fuel fabrication costs. (See Chart XIII.)

[7] Fuel material lease costs for the Enrico Fermi and Rowe stations will be waived by the AEC for at least part of the initial three years.

[8] Cost of replaceable core structures and controls is highly uncertain. This has been reflected in the uncertainty estimates.

[9] Dresden station estimates are based on burnups to be achieved by shuffling fuel. The Indian Point station will use multi-zone enrichment. The uncertainties in the Rowe station estimate reflect the possibility of using multi-zone enrichment in the first and second cores. Enrico Fermi estimates are based on biweekly changes of part of a core load.

[10] Based on uncertainties in attainable burnup.

[11] The large number of core changes during the initial operating period affords opportunity for introducing improved cores more rapidly than in other stations.

[12] Plant utilization factor, $\frac{\text{net ekwhr/yr}}{\text{rated net ekw} \times 8760}$, is assumed to be 0.7 during initial operation. Actual plant factor during this period may be significantly higher or lower. However, only large changes in plant factor have significant effect on fuel costs.

the Appendix. They are intended to cover the first three years of station operation after the rated performance and anticipated availability of a plant have been achieved.

There is an understandable tendency to examine the figures of Table II from the standpoint of what they may indicate regarding the relative cost performance of individual plants or plant types. This should be done with care, if at all, because the large uncertainties in the estimates may mask real differences; the assumptions used for consistency in this report may not strictly apply in specific cases and estimates of fuel costs for future operations may be significantly different than for initial operation.

As noted in the table, the estimates are for specific fuel cores and reactors at various stages of design and development. They do not necessarily represent inherent differences in the economics of basic types of fuel cores or reactors.

As shown in Table II, the uncertainties approximated for any particular cost estimate indicate that there is a significant chance that actual fuel costs will be lower or higher than the nominal costs presented in the table. The application of these uncertainties also indicates that there is a possibility of nuclear fuel costs being comparable to conventional fuel costs during the first three years of operation of some stations. The lowest estimates range from about 2 mills/ekwhr for Dresden station to about 3 or 5 mills/ekwhr for the Rowe and Indian Point stations, based on the assumption that the value of plutonium is $30/gram.

The nominal fuel cost estimate for the Enrico Fermi station is somewhat higher than for the other plants, except Shippingport. However, the Enrico Fermi station is the pioneering effort to build a large fast breeder reactor and is at an earlier stage of development than the water reactors.

During the initial three years of operation of the Enrico Fermi station, between 5 and 14 complete core changes are expected, whereas, at most, less than three will be made in the water-cooled reactors. Therefore, it has been assumed that the average fuel fabrication cost for each core during the initial three years of operation of the Enrico Fermi station will be about 70 percent of the fabrication cost for the first core.

The fuel cost estimate for the Shippingport station given in the first column of Table II is based on conservative estimates of fuel lifetime made before the reactor started up. The second column is based on what is believed to be a more realistic estimate of fuel burnup, substantiated to a certain extent by information obtained during startup. The third column illustrates the small effect on unit fuel cost of increasing power output.

The Shippingport costs are very high, primarily because of high fuel fabrication cost. Reconciliation of the Shippingport fuel fabrication cost with estimates for other large stations is discussed in the fuel fabrication section of this report.

UNCERTAINTIES IN NUCLEAR FUEL COST ESTIMATES

Analysis of uncertainties in nuclear fuel cost estimates is essential for an understanding of the reliability and possible range of variation of these estimates. However, rigorous analysis is not yet possible because practical information from manufacturing and operating experience is lacking and because of mathematical problems explained in the Appendix. Nevertheless, causes of uncertainties in each of the elements of fuel cost have been identified, their magnitude roughly estimated and their effect on total fuel cost approximated.

The uncertainties in total fuel costs shown in Table II represent a transitory situation typical of a period before large-scale manufacturing and operation have commenced. After several years of operating experience these uncertainties should be substantially reduced for the specific types of fuel used.

The possibility of changes in government prices for plutonium, enriched uranium and other fissionable materials is not included in the estimated uncertainties. However, estimates of the effect of the variation in plutonium prices on total fuel cost are given in Chart II.

An important criterion used in developing uncertainty estimates for each cost and performance factor was that the possible limits of variation of each factor should be chosen so that there would be less than a 10 percent chance that actual variations would exceed these limits.

Uncertainty estimates for each fuel cost and performance factor were obtained from the responsible designers and cost estimators for each station. Where possible, this information was cross-checked from plant to plant and compared with information from operating prototype reactors and fuel processors. The uncertainties in each factor were then combined by the methods described in the Appendix.

Uncertainties in total fuel cost (mills/ekwhr) are dominated by probable errors in predicted burnup. For the three water reactors the uncertainties in burnup, as limited by reactivity, are estimated to be in the range of +50 to +100 percent and −10 to −50 percent around the nominal burnups shown in Table II. If reactivity limits are lower than expected, remedies such as those discussed under the subheading "Increases in Burnup" may be applied.

The small amount of test information and experience available indicates that for the water

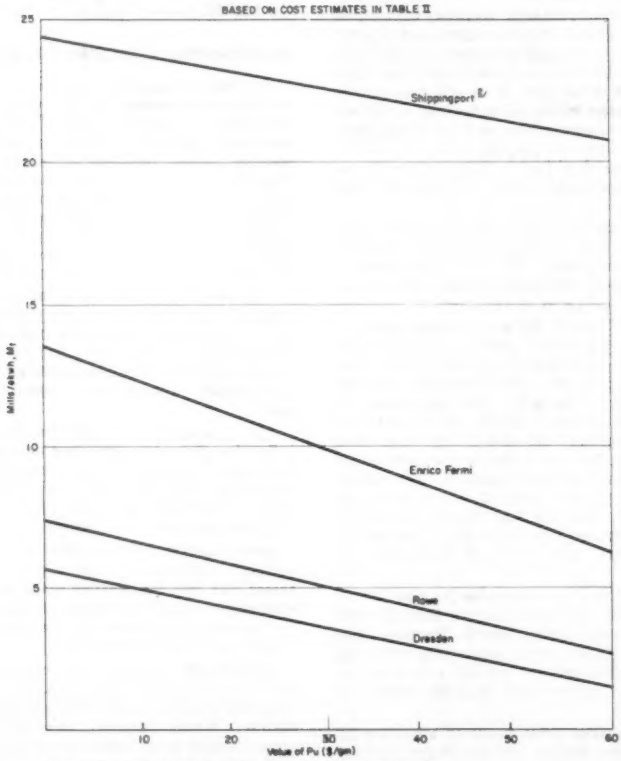
ing initial operation. Actual plant factor during this period may be significantly higher or lower. However, only large changes in plant factor have significant effect on fuel costs.

in time from payment of prepaid costs to receipt of compensating revenue, variations in the cost of money and changing fuel fabrication costs. (See Chart XIII.)

Chart II

VARIATIONS OF FUEL COST WITH PLUTONIUM VALUE [1]

BASED ON COST ESTIMATES IN TABLE II



[1] The Indian Point plant is not included, since initial operation does not involve the production of plutonium.

[2] For 60 cent rated operation at 0.7 plant factor, with burnup in the core of 30% and in the seed of 0.53%.

reactors for the period covered the uncertainty in attainable burnup due to the possibilities of mechanical failure of fuel is probably less than that due to reactivity limits. Therefore, it has been assumed that reactivity will limit burnup in these cases.

For the Enrico Fermi reactor, experimental information indicates that attainable burnup will be limited to about 1 percent by radiation damage. Actual burnup for the type of core used initially may be higher or lower than this. Also, it may be possible to develop and use improved cores during the first three years of operation which will attain higher burnup than the first core type. Therefore, average attainable burnup for initial operation of the Enrico Fermi plant is estimated to lie between 0.7 and 2 percent.

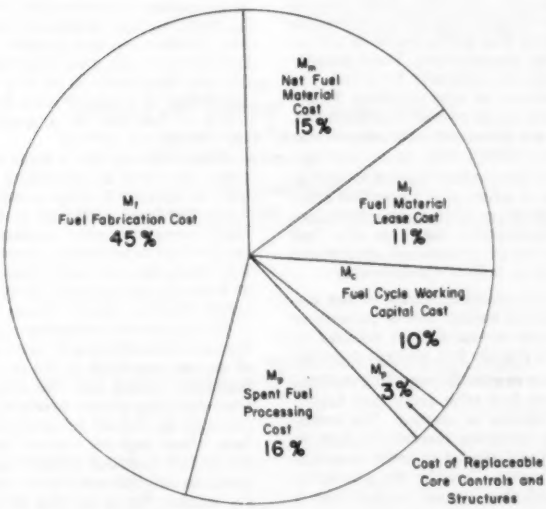
An important element affecting uncertainties in total fuel cost is the cost of processing fresh and spent fuel. These uncertainties are estimated to be within the range of ±30 percent. Uncertainties in net station efficiency and the energy of fission are smaller. They are estimated to be ±10 percent and ±5 percent, respectively, for all of the stations.

Chart III

ELEMENTS OF NUCLEAR FUEL COST

For Initial Operation of a Typical Large Station

(Assuming the value of plutonium is $12 per gram)



RELATIVE IMPORTANCE OF ELEMENTS OF FUEL COST

Chart III illustrates the approximate magnitude of the various elements of fuel cost for a typical case. This example is based on the initial operation of the large water reactors and on a plutonium value of $12 per gram.

Fuel fabrication cost in the types of large reactors now under construction is by far the largest element of fuel cost, as indicated on Chart III. If plutonium is worth $12 per gram, fabrication costs are about 75 percent of the total for Shippingport, 45 percent for Enrico Fermi, 34 percent for Indian Point, 55 percent for Rowe and 47 percent for Dresden.

Net fuel material cost, with $12-per-gram plutonium, varies between 10 and 15 percent of the total for Enrico Fermi, Rowe and Dresden. It is a smaller percentage for Shippingport (approximately 5 percent) because of the relatively high fuel fabrication cost and a larger percentage for Indian Point (approximately 40 percent) because of the relatively high cost of the highly enriched uranium burned in its initial operation and the relatively small fraction of energy derived from fertile material. If the plutonium credit is $30 per gram, the net fuel material costs for Fermi, Dresden and Rowe become negative, denoting a net credit for fuel.

Spent fuel processing costs, with $12 plutonium, are from 15 to 20 percent for Indian Point, Rowe and Dresden, and 3 to 4 percent for Shippingport. Fuel material lease cost varies between 8 and 20 percent for all except the Shippingport station, where it is a much lower percentage of the total cost. Fuel cycle working capital cost varies between 5 and 15 percent of the total. The cost of replaceable core structures and controls is a small percentage of the total.

FUEL PRICES AND PERFORMANCE GUARANTEES

From the point of view of a nuclear power plant operator, one practical method of minimizing the financial risk due to uncertainty in fuel costs is to

obtain guarantees on fuel performance and fixed prices for fuel processing and manufacturing.

Firm prices can be obtained from fuel manufacturers and processors for most of the fresh fuel processing and scrap recovery steps. These prices usually include guaranteed yields, specifications and insurance. Firm arrangements can also be made with the government for the lease of fuel material, spent fuel processing and waste disposal.

Guarantees are now available from reactor manufacturers providing partial financial restitution in case designed fuel performance is not attained with fuel they manufacture. These guarantees for large plants are generally for rated core power and for burnups of approximately 10,000 tmwd/t. In one case, under special circumstances, the manufacturer has guaranteed the mills/ekwhr fuel cost itself for a limited time.

In typical burnup guarantees the fuel manufacturer will warrant, in effect, that a specified average amount of heat energy can be obtained before any fuel failure necessitates discharge of a fuel element. Types of failure guaranteed against are in various cases one or both of the following:

1. Mechanical or corrosion failure of the element — impeding coolant flow or permitting sufficient fission products to be released in the coolant to require fuel element removal.
2. Loss of nuclear reactivity, requiring replacement of spent fuel with fresh fuel before guaranteed lifetime is reached. The manufacturer may, however, reserve the right to have the fuel rearranged in order to attain guaranteed burnup. Usually the guarantee applies to each fuel element rather than a complete core.

The financial responsibility of the guarantor is in most cases limited to fuel fabrication costs, prorated in accordance with burnup achieved compared to that guaranteed.

The fact that fixed prices for fuel fabrication are offered and that fuel performance guarantees can be obtained reflects increasing knowledge and confidence on the part of manufacturers that they can predict fabrication costs and fuel performance characteristics.

BURNUP

Burnup is defined in this report as the percent of fertile and fissionable atoms fissioned before fuel is discharged. Since burnup is often expressed as thermal megawatt days per ton (tmwd/t), it is shown in both ways on the charts.

At the present time burnup is the most important element affecting nuclear fuel costs. It is probably also the most uncertain element, and the one most easily subject to initial improvement.

The fuel cost formula previously cited:

$$M_t \text{ (mills/ekwhr)} = \frac{C_t}{2.2\,BX}$$

indicates that total fuel cost, M_t, is inversely proportional to burnup, B. This is approximately correct for early operation of large U. S. stations now being constructed which have high fuel fabrication and processing costs. If lower fuel fabrication and processing costs can be achieved, burnup will be relatively less important, primarily because it has no effect, or only a small effect, on net fuel material cost, M_m, fuel cycle working capital cost, M_c, and fuel material lease cost,, M_l. Chart IV illustrates, in a typical case, how the various elements of fuel cost for a specific core depend on the burnup.

Where burnup has a large effect on total fuel costs, increases in processing or material costs may be justified in order to obtain higher burnup. Thus, increased costs due to higher enrichment, lower conversion ratio, increased loading, higher quality fuel fabrication, repositioning of fuel before discharge, dual enrichment zones and the use of burnable poisons may, if they significantly increase burnup, result in lower over-all fuel costs.

Two kinds of phenomena may limit burnup — the loss of reactivity and mechanical failure. Loss of nuclear reactivity is due to the consumption of fissionable atoms and the accumulation of neutron-absorbing fission products. Mechanical failure may be caused by structural failure of the fuel, which impedes coolant flow, or by the failure of fuel cladding, permitting release of fission products into the coolant to such an extent that the reactor has to be shut down for removal of defective fuel pieces.

Reactivity Limits on Burnup. There is a large uncertainty in attainable burnup for most reactors at this stage of reactor development due to the difficulty of predicting the amount of nuclear reactivity which will be available during operation over a long period of time. Such predictions depend upon calculations from inexact measurements of physical properties and upon uncertain assumptions concerning physical conditions in the fuel core during operation.

Chart V shows how the excess nuclear reactivity available to operate the core varies as fuel is burned in a large uranium-water reactor similar to those considered in this report. The case illustrated is one in which fuel is not repositioned before discharge. As can be seen, small changes in the slope of the reactivity curve can result in significant changes in reactivity lifetime. There is a considerable degree of uncertainty in predicting the slope of this curve.

While preliminary data being developed in small reactors may provide helpful information concern-

ing the reduction of uncertainties in burnup as limited by reactivity, significant information can only be obtained after cores of the large reactors are operated for a considerable time.

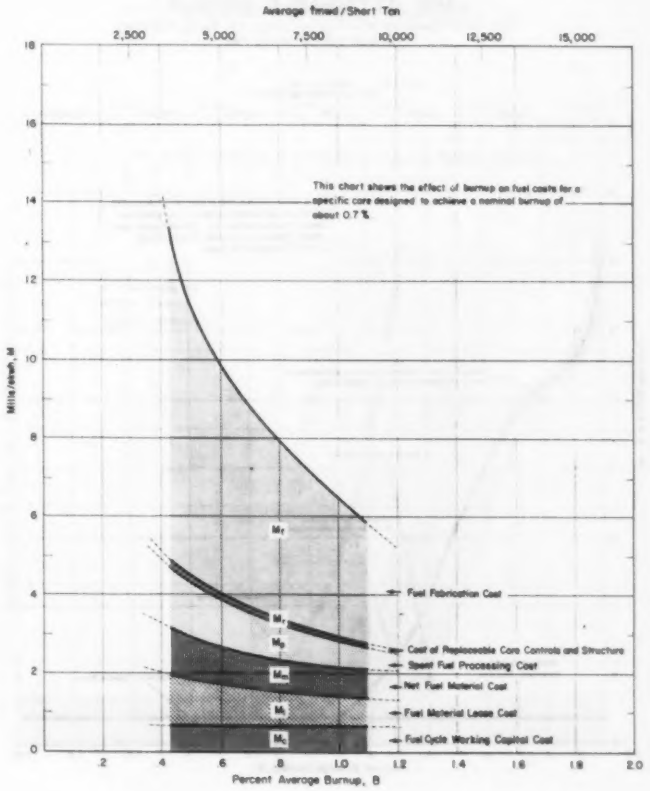
Another uncertainty in predicting the reactivity limits on burnup before operations start derives from inaccuracies in estimating the amount of initial excess reactivity at operating pressure and temperature. However, because zero power critical mockups of core assemblies can be made, it is believed that currently available techniques for extrapolating mockup results to operating pressure, temperature and fuel configuration will permit the prediction of initial reactivity within ±10 percent. As experience is gained with particular reactor types, these mockups will become unnecessary.

Mechanical Limits on Attainable Burnup. A major step in improving the mechanical lifetime of natural and slightly enriched uranium fuel has been the development of useful forms of uranium oxide (UO_2). Although this fuel has some im-

Chart IV

EFFECT OF BURNUP ON FUEL COSTS

For Initial Operation of a Typical Large U.S. Nuclear Power Station
(Slightly Enriched Fuel, Light Water Cooled)


Average Irrad./Short Ton
2,500
5,000
7,500
10,000
12,500
15,000
Mills/kwh, M
This chart shows the effect of burnup on fuel costs for a specific core designed to achieve a nominal burnup of about 0.7 %
Fuel Fabrication Cost
Cost of Replaceable Core Controls and Structure
Spent Fuel Processing Cost
Net Fuel Material Cost
Fuel Material Lease Cost
Fuel Cycle Working Capital Cost
Percent Average Burnup, B

portant shortcomings, such as low thermal conductivity, it is more stable in the presence of water and radiation than the metallic fuels. No apparent unacceptable mechanical damage occurs to well-constructed dense UO_2-pellet fuel at burnups in excess of 3 percent, provided it is not subjected to heat fluxes considerably beyond those planned for the large U.S. stations.

In the large stations, except Enrico Fermi, mechanical lifetime must be from one to four years to match expected reactivity lifetime. Although many tests have been made on individual parts of fuel elements and a few complete elements, less than 1 percent of a large core load has been carried to burnup levels planned for large stations. (Some of the test results are given in the Appendix.) Therefore very little knowledge has been obtained on a statistical basis as to the probability of fuel failure for the several specific types of fuel planned for stations under construction.

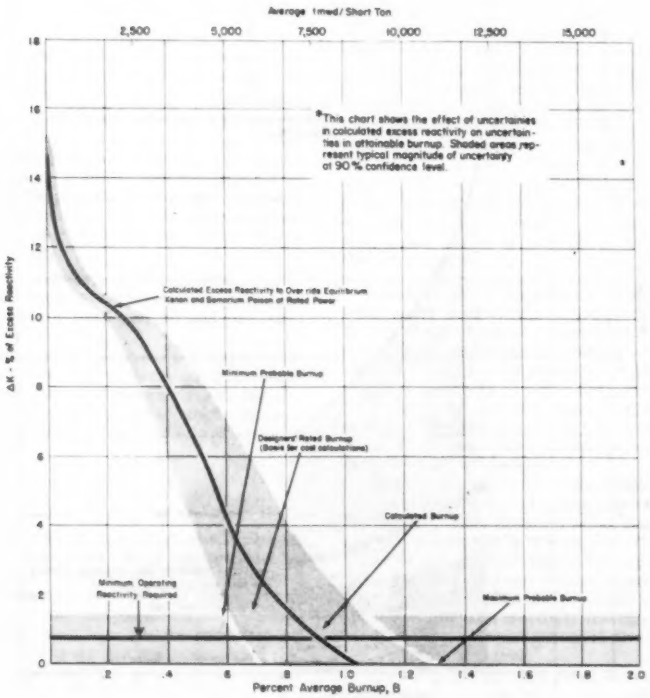
This information cannot be obtained for power reactors until full-scale, or at least a few small or medium-sized, plants have been operated for an appreciable period. Performance of natural uranium-dioxide pellets in the Shippingport reactor blanket will provide important statistical data. However, it will take at least another year of operation to approach significant burnup levels.

Although the first large stations are designed so that they can continue to operate with a number of

Chart X

EXCESS REACTIVITY AND ATTAINABLE BURNUP *

For Initial Operation of a Typical Large U.S. Nuclear Station Without Repositioning Fuel


Average tmwd/ Short Ton
2,500
5,000
7,500
10,000
12,500
15,000
*This chart shows the effect of uncertainties in calculated excess reactivity on uncertainties in attainable burnup. Shaded areas represent typical magnitude of uncertainty at 90% confidence level.
Calculated Excess Reactivity to Override Equilibrium Xenon and Samarium Poison at Rated Power
Minimum Probable Burnup
Designers' Rated Burnup (Basis for cost calculations)
Calculated Burnup
Minimum Operating Reactivity Required
Maximum Probable Burnup
ΔK - % of Excess Reactivity
Percent Average Burnup, B

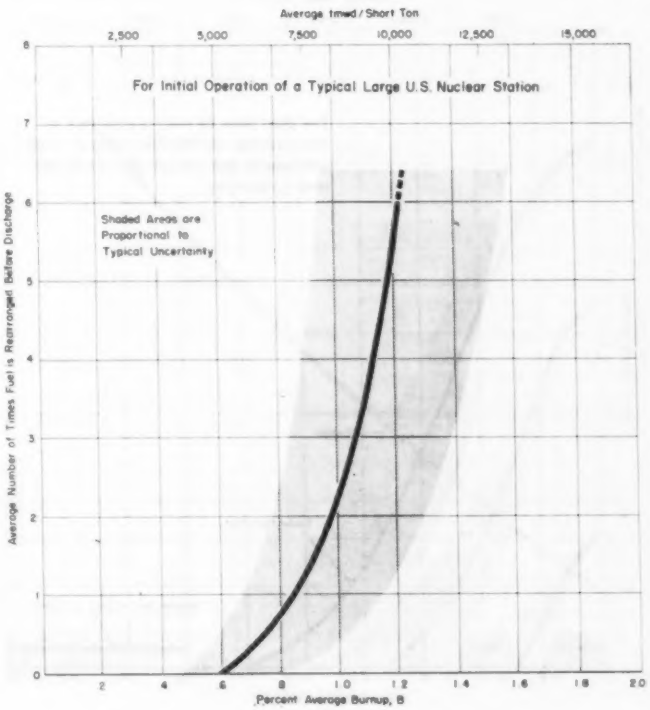
fuel failures, and although present limited tests indicate that the mechanical life of fuel should be in excess of planned burnup, there may still be a significant chance that unacceptable failure rates may be encountered in UO_2 fuels. Long-term corrosion resistance of cladding is perhaps the largest unknown. In the early years of operation the uncertainty in mechanical lifetime of oxide fuel is, however, believed to be less than that in reactivity lifetime for all plants except the Enrico Fermi.

Increases in Burnup. Higher burnups than presently planned are probably necessary in order to achieve economic nuclear power with reactor types dealt with in this report. To increase burnup it will be necessary to increase both the mechanical and reactivity lifetime of the fuel.

Major increases in burnup may be achieved by rearranging the fuel one or more times before it is discharged or by using several enrichment zones in one core in order to extend the reactivity lifetime of the fuel. The nominal burnup shown in Table II for the Dresden plant is based on plans for rearranging fuel. Multi-zone enrichment will be used in the first core of the Indian Point station. Neither multi-zone enrichment nor fuel rearrangement are planned for the first core of the Rowe station. However, the uncertainties shown in Table II are based on the assumption that a decision to rearrange fuel or use multi-zone loading

Chart XI

RADIAL REARRANGEMENT OF FUEL AND ATTAINABLE BURNUP



may be made which will affect the initial operating period.

The effect of fuel rearrangement on burnup for a typical water reactor is illustrated in Chart VI. In this case the fuel elements are placed in the core vertically, and are long and thin. After the reactor has been operated for some time, the center fuel elements can be removed and the outer fuel elements moved in radially to replace the inner ones. Then fresh fuel elements can be added around the periphery. This is "outside-in" rearrangement. "Inside-out" rearrangement has also been studied.

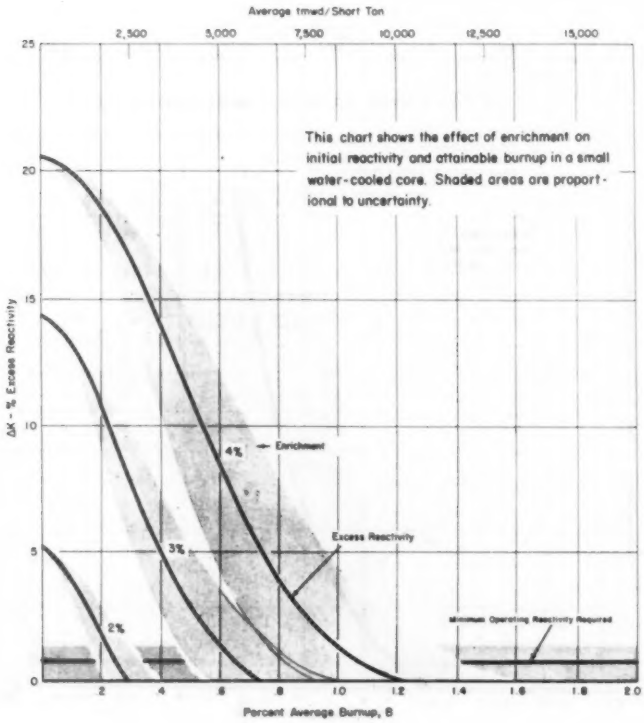
In a typical case, one radial rearrangement for each fuel element before it is discharged would result in about a 30 to 50 percent increase in average reactivity lifetime, compared to a case where no rearrangement was made. Two rearrangements would result in an increase of about 50 to 60 percent and three in about 60 to 70 percent.

Rearrangement of fuel elements can also be beneficial by lowering the maximum-to-average exposure ratio of the fuel, increasing specific power and reducing the amount of excess reactivity required to achieve a given reactivity lifetime.

There is a practical limit to the number of rearrangements which can be made before fuel is discharged. This is determined by the degree of difficulty of rearranging the fuel. In water-cooled reactors with relatively short fuel residence times, only one or two rearrangements might be practical

Chart XII

ENRICHMENT AND ATTAINABLE BURNUP



with present equipment due to the difficulty of refueling. Dual- or multi-enrichment zone loading may be more useful in such cases. Where average fuel residence is longer, as many as four to six rearrangements might be made before fuel is discharged.

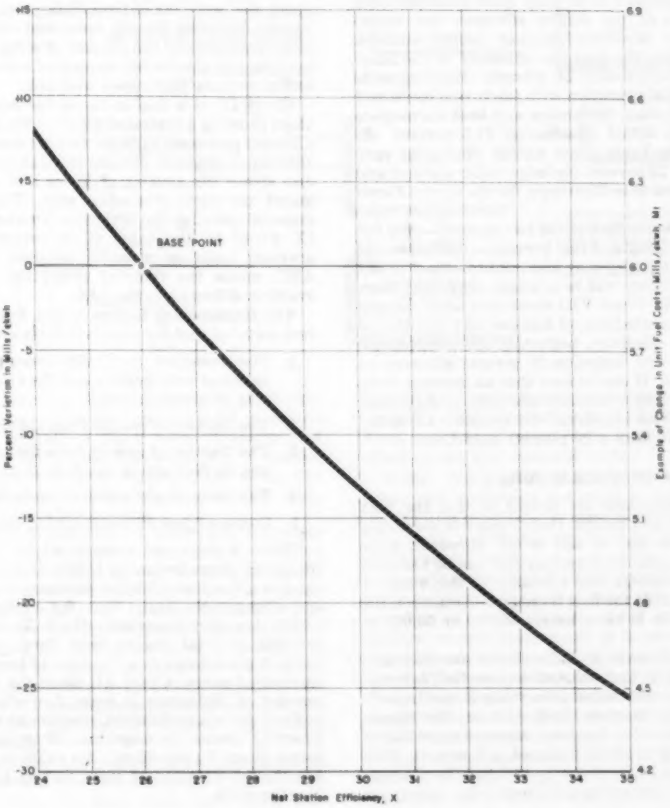
Another method for extending the reactivity limit on burnup is to replace fuel very frequently in small batches. This type of operation is planned for the Enrico Fermi station and has been studied for plutonium-production reactors and for the Canadian and British gas-cooled reactors. Still another way is to increase initial reactivity (if the control system can accommodate it) by adding enrichment or by increasing the fuel load.

An example of the effect of enrichment on initial reactivity and attainable burnup in a water-cooled power reactor is given in Chart VII.

Most reactors have a negative temperature coefficient, which means that if the temperature of the core is lowered they become more reactive and if it is raised they become less reactive. It may be

Chart VIII

VARIATION OF UNIT FUEL COST WITH NET STATION EFFICIENCY



permissible in certain special cases to lower temperature somewhat to obtain additional reactivity.

NET STATION EFFICIENCY, X

Total unit fuel cost, M_t, is inversely proportional to the net station efficiency, X. Therefore, major improvements in station efficiency can result in direct and important reductions in fuel cost as well as capital cost. However, for the first large stations, improvement of net station efficiency over the design values will probably be impractical. This would involve cutting down the requirement for internal station power, such as for pumping, or raising temperatures to increase thermal efficiency. These things will be difficult to do after the stations are designed or in operation.

There appears to be very little uncertainty in predictions of net station efficiency for water-cooled and -moderated nuclear electric stations. For example, the expected efficiency of the Shippingport station was 26 percent. Measurements during initial operation with fairly cold condenser water and clean condensers and heat exchangers indicate an actual efficiency of 27.5 percent. As indicated in Table I, net station efficiencies vary from 26 to 29 percent for large water stations and are predicted to be 33 percent for the Enrico Fermi plant.

It is probable that of the two factors — the net station efficiency and fuel burnup — the latter will be easiest to improve at first; improvement of net station efficiency will be a longer range and more difficult task. Chart VIII illustrates what changes might be expected in unit fuel cost as a function of net station efficiency, neglecting any countervening effects, and assuming 26 percent efficiency as a base point. It can be seen that an increase from 26 to 33 percent net station efficiency would reduce fuel costs from a nominal 6.0 to about 4.7 mills/ekwhr, more than a 20 percent reduction.

HEAT VALUE OF NUCLEAR FUEL, E

Fissionable fuels are unique in that the heat content per unit weight (heat value) is about 2½ million times that of coal or oil. However, since only 1 or 2 percent of nuclear fuel can be fissioned during one charge into a reactor at this stage of the operation of the first large power reactors, the effective ratio is more nearly 25,000 or 50,000 to one.

Since fuel costs in mills/ekwhr are inversely proportional to heat value of nuclear fuel, assumptions and uncertainties concerning it are important. For the reactors dealt with in this report, nuclear heat value has been assumed to be 2.2×10^7 tkwhr/kg of atoms fissioned, ±5 percent. This is equivalent to about 3.4×10^{10} Btu/lb of atoms fissioned, or 196 million electron volts (mev) per fission. The basis for the assumption is given in the Appendix.

NET FUEL MATERIAL COSTS, C_m

Net fuel material costs are defined as the value (or cost) of fuel material in the form in which it is procured for processing prior to use, minus credit (or revenue) for that portion of the same material recovered from scrap or spent fuel, for re-use.

In computing net fuel material costs, the values of enriched and depleted uranium, plutonium, U-233 and mixtures of U-233 and U-235 are based on AEC value schedules. The costs of natural uranium and thorium are based on current selling prices. Estimates of the required composition of fresh fuel material and of the average composition of spent fuel were taken from data prepared by the reactor designers directly concerned with each station. Estimates of the amount of scrap and losses are based on the limited amount of manufacturing and processing experience available.

Chart IX is a fuel material balance and flow chart showing a typical example of the amounts of material processed through various steps for each 1000 kg of uranium passing through a reactor. It also shows the amount of losses and scrap estimated for each processing step. The net fuel material costs for the fuel cycle depicted in Chart IX would be the value of 10-percent-enriched uranium make-up material obtained from the AEC, minus the value of plutonium and scrap uranium delivered to the AEC.

The fundamental factors which determine net fuel material cost for uranium fuels are:

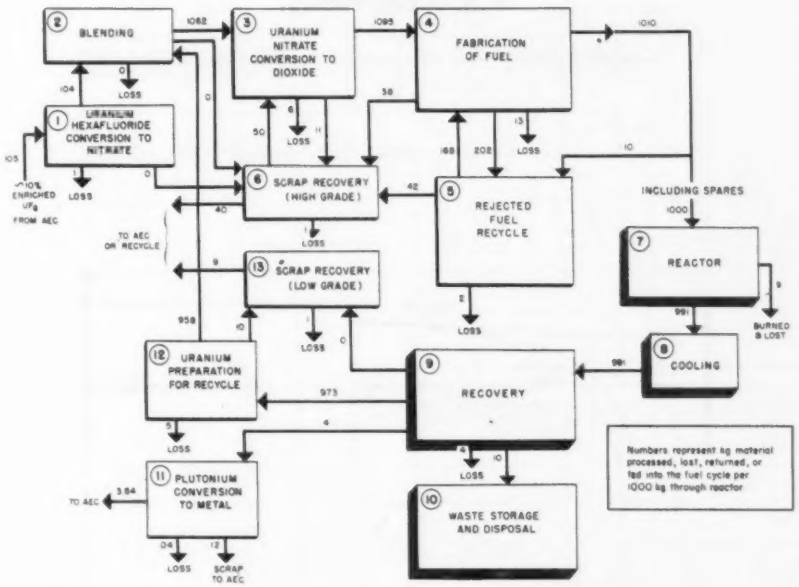
1. The reduction in U-235 concentration in uranium with burnup and the related depletion of uranium value;
2. The fraction of energy from U-235 fissioned;
3. The fraction of energy from fission of U-238 and its derivatives (such as plutonium);
4. The value of plutonium in spent fuel;
5. Losses of fuel material during processing.

Chart X shows an example of the basic cost of energy from fissioning U-235 (item 1 preceding) as a function of initial enrichment and burnup. Comparable basic costs for plutonium and U-233 are also indicated. Chart XI shows the fraction of total energy from fertile materials (item 3 preceding) as a function of burnup for a number of cases. Chart XII gives the calculated amount of plutonium in spent fuel (item 4 preceding) for many different reactors and burnups. Chart IX shows the magnitude of typical process losses (item 5 preceding). An example illustrating the interrelation of these factors is given in the Appendix.

Chart IX

TYPICAL FUEL MATERIAL BALANCE

FOR SLIGHTLY ENRICHED UO_2 FUEL CLAD WITH STAINLESS STEEL


2 BLENDING
3 URANIUM NITRATE CONVERSION TO DIOXIDE
4 FABRICATION OF FUEL
1 URANIUM HEXAFLUORIDE CONVERSION TO NITRATE
6 SCRAP RECOVERY (HIGH GRADE)
5 REJECTED FUEL RECYCLE
7 REACTOR
INCLUDING SPARES
13 SCRAP RECOVERY (LOW GRADE)
8 COOLING
BURNED & LOST
12 URANIUM PREPARATION FOR RECYCLE
9 RECOVERY
11 PLUTONIUM CONVERSION TO METAL
10 WASTE STORAGE AND DISPOSAL
LOSS
TO AEC OR RECYCLE
FROM AEC
TO AEC
SCRAP TO AEC
Numbers represent kg material processed, lost, returned, or fed into the fuel cycle per 1000 kg through reactor

Examination of Chart X shows that plutonium worth $30 per gram (the present AEC minimum value) is basically a much more expensive fuel than U-235 or U-233. Consequently, a reactor operator would want to maximize the amount of plutonium produced and minimize plutonium burn-up, other things being equal.

However, if plutonium is worth $12 per gram, it may be cheaper fuel than U-235 enriched above 2 or 3 percent, and may be about the same as U-233 fuel or U-233–U-235 mixtures. Therefore, while it might still be advantageous to produce as much plutonium as possible, the economical course might be to burn as much as possible in place. There are many factors which may modify this basic situation in specific cases, including consideration of the relative processing, manufacturing and spent fuel recovery costs of the various fuel materials.

Uranium losses in processing are expected to be 2 to 4 percent per processing cycle for slightly enriched fuels. In these fuels such losses may account for from 1 to 5 percent of total fuel costs, becoming a larger fraction as enrichment is increased. With intermediately and highly enriched fuels, processing losses have a more important effect on net fuel material costs.

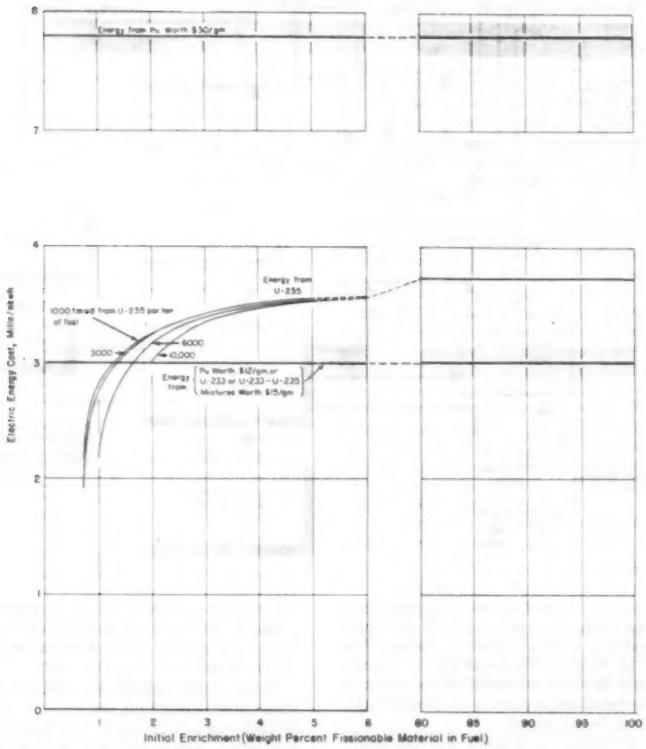
Scrap rates can have a significant effect on losses and, in addition, can result in delay of credit if the scrap processing is time consuming. Therefore scrap processing can have an effect on net fuel material costs.

Uncertainties in net fuel material costs are large and highly variable. They range in the cases investigated from ±20 to ±150 percent. The highest uncertainties result in those cases where net fuel material cost is derived from a relatively small difference between several large numbers. Even if uncertainty in these large numbers is small, the uncertainty in the small difference between them can be very large.

However, where uncertainties in net fuel material cost are largest, net fuel material cost is small. The effect on total fuel cost uncertainty of large uncertainties in small net fuel material costs can

Chart X

BASIC DEPLETION COST FOR VARIOUS TYPES OF NUCLEAR FUELS [1]


Energy from Pu Worth $30/gm
Electric Energy Cost, Mills/kwh
Energy from U-235
1000 lbs of from U-235 per ton of fuel
3000
6000
10,000
Energy from
Pu Worth $12/gm, or
U-233 or U-233 - U-235 Mixtures Worth $15/gm
Initial Enrichment (Weight Percent Fissionable Material in Fuel)

(1) Assuming: AEC price schedules, recovery costs not included, thermal neutron fission, @ 25% net station efficiency.

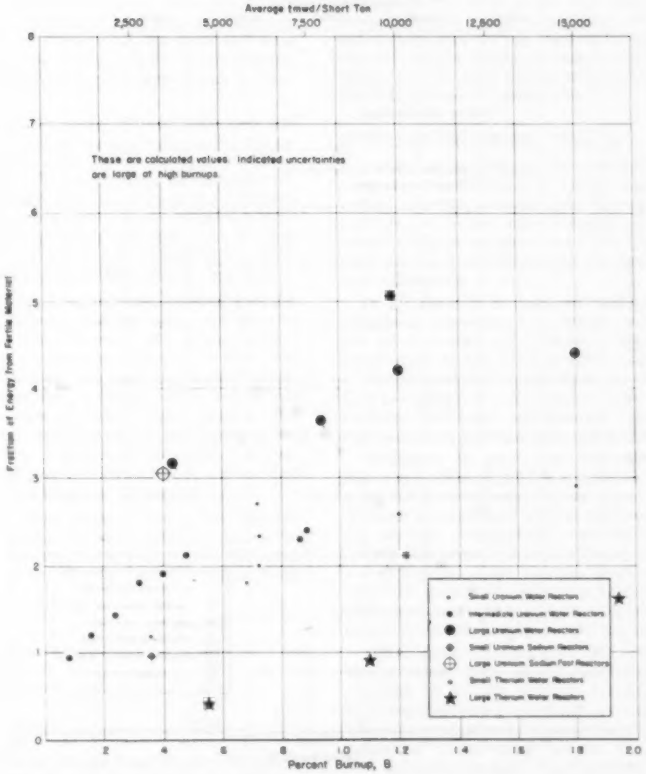
be about the same as smaller uncertainties in larger costs.

FUEL FABRICATION COST, C_f

Fuel fabrication costs and the uncertainties in them for the five stations covered in this report are derived from cost records for Shippingport; extrapolation of firm contracts for Enrico Fermi; and estimates, proposals and subsidiary contracts for Dresden, Rowe and Indian Point. They have been checked against each other for reasonable correlation and have been examined in the light of recorded costs, contracts, proposals and estimates for other reactors with similar fuel. Effort has been made to see that they are on a consistent basis, particularly regarding treatment of research and development, facility write-off and overhead costs. In addition, allowance has been made for possible differences in cost basis when assessing the uncertainties associated with fuel fabrication cost in each case.

Chart XI

FRACTION OF ENERGY FROM FERTILE MATERIAL



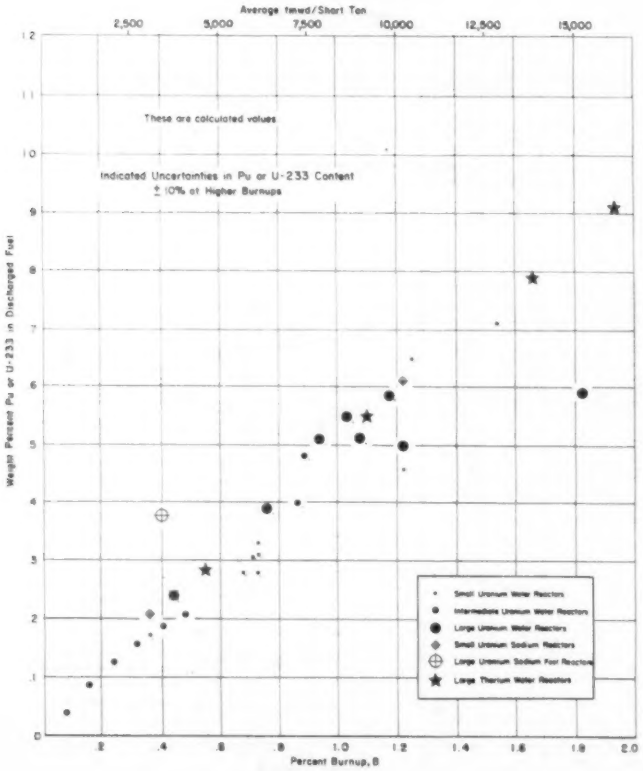
Fuel fabrication includes all of those steps necessary to convert fuel material as procured into finished and accepted fuel elements. Steps 1 through 6 of Chart IX illustrate the types of processes included in fuel fabrication. A more detailed definition of the fuel fabrication cost is given in the Appendix.

Uncertainties in fuel fabrication costs were developed for each station through discussions with the fuel manufacturer or utility company involved. These uncertainties, when expressed as a percent of fabrication cost, C_f, in \$/kgU, varied from ± 25 percent in one case to ± 35 percent in another.

One of the most striking differences in fuel fabrication cost shown in Table II is that between the Shippingport station estimate and the estimates for the other stations. An approximate reconciliation of these unit fuel costs can be made by comparing the Shippingport blanket elements, similar in general concept, to fuel for the other water-cooled reactors. Records indicate that the manufacture of these blanket elements cost approximately \$550/kgU, but, of this, about \$266/kgU was for the procurement of zirconium tubes and other zirconium pieces, \$53/kgU was for making UO_2 pellets and only \$231/kgU was

Chart XIII

RANGE OF PLUTONIUM OR U-233 CONTENT IN SPENT FUEL



for fabrication and assembly of the finished elements.

Stations are now being built which have fuel elements containing about half as much zirconium per kilogram of uranium as the Shippingport blanket fuel. Also, it has been estimated that with reduced scrap losses the ratio of purchased-to-fabricated zirconium will be at most two-thirds that experienced for Shippingport. Therefore, without assuming any reduction in the basic cost of zirconium raw material, the unit cost of zirconium in an improved reactor might be:

$\$266/\text{kgU} \times \frac{1}{2} \times \frac{2}{3} =$ approximately $\$90/\text{kgU}$.

Other things being equal, it appears that fabrication costs for oxide-type fuels are roughly proportional to surface area of the fuel, rather than to the fuel weight. Therefore, the cost in dollars per kilogram of uranium should be proportional to surface area per kilogram of fuel. It would be expected that the Shippingport blanket fabrication cost of $\$231/\text{kgU}$ might be reduced by the ratio of surface areas to the unit weight of fuel. For example, for a 0.5-inch diameter fuel, the ratio

$$\frac{0.36}{0.5}$$

would be about $\frac{0.36}{0.5}$, reducing the fabrication cost to $\$166/\text{kgU}$.

There has been a reduction in the unit fabrication cost of the UO_2 pellets, due to a reduction in tolerances. The Shippingport tolerances were very tight — about +0.0000, −0.0005 inch on pellet diameter of 0.3625 inch and +0.000, −0.001 inch on a length of 0.348 inch. There was also a squareness tolerance of 0.0004 inch for each end with respect to the axis and a surface finish requirement of 32 microinches rms (root mean square) or better.

It is believed that less stringent tolerances will be acceptable. This will result in a considerable reduction in pellet manufacturing cost by eliminating the necessity for grinding all the pellets to meet tolerances. Pellets can be made to a tolerance of ±0.001 or ±0.002 inch without grinding a large portion of them. For this and other reasons, it is assumed that a reduction from $53/kgU to $15/kgU in the pellet fabrication cost is possible.

The pioneering Shippingport blanket fuel elements are relatively complex compared to later designs. They are comprised of a large quantity of fairly short fuel rods welded shut on both ends and then welded at both ends again into a subassembly. More recent designs tend toward the use of longer rods and mechanical fastenings for subassemblies, requiring much less welding and weld inspection. Simpler designs and improved inspection methods are expected to reduce fuel fabrication costs by about 50 percent.

Hence, it is reasonable to assume that the following unit fabrication cost might be obtained for a zirconium reactor core similar to the Shippingport blanket, but differing from it as previously described:

	$/kgU
Zirconium cost	90
Pellet cost	15
Fabrication cost	100
Total	205

The unit cost of energy from the first Shippingport blanket which is attributable to fuel fabrication is around 18 mills/ekwhr. Since fuel fabrication cost in mills/ekwhr is directly proportional to fabrication cost in $/kgU, the 18 mills would be reduced by the ratio of 205 to 550. In addition, the average burnup assumed in the Shippingport blanket estimate cited before is 0.57 percent. This compares with estimates of around 1.2 percent assumed for other cores, so a further reduction of $\frac{0.57}{1.2}$ can be expected. The resulting cost is:

$$18 \times \frac{205}{550} \times \frac{0.57}{1.2} = 3.19 \text{ mills/ekwhr.}$$

This is roughly consistent with the estimates for fuel fabrication for other large stations in Table II. However, still further reductions in this comparative cost might be expected, due to the larger size of other cores, improved fabrication techniques now under development in addition to those mentioned before, increased production in the fabrication plants, reduced basic zirconium prices, and the development of know-how with further experience in fabrication.

SPENT FUEL PROCESSING COST, C_p

Spent fuel processing cost includes the cost of all processing necessary to convert fissionable and fertile materials in spent fuel elements to a form suitable for re-use, sale or credit, provided it is worth while to recover them. The types of processes involved are illustrated by steps 9 through 13 on Chart IX.

In all cases it is assumed that cladding and structural materials (including zirconium) will not be recovered and, therefore, that no cost is attributable to this kind of activity. Also, the loss of fertile and fissionable material during spent fuel processing is not included, since it has been included in the net fuel material cost. Shipping, insurance and storage costs are included.

Estimates of spent fuel processing costs are based primarily on AEC's acceptance of responsibility for the recovery of spent power reactor fuel through the middle of 1967 if commercial processing services at reasonable cost are not available during this period. It is therefore assumed in this report that no large changes from present estimates of spent fuel recovery costs will occur and that there is about a ±20 to ±30 percent uncertainty in uranium and plutonium recovery cost.

Other uncertainties in the total spent fuel processing costs, such as in converting recovered uranium to a form suitable for credit or sale, shipping and scrap recovery, are also important. These uncertainties are due to possible changes in operating plans, which govern the batch sizes, and possible changes in processing costs, shipping, insurance and scrap recovery costs.

The over-all uncertainties in the cost of spent fuel processing were estimated for each case to be less than ±30 percent of the spent fuel processing cost expressed in $/kgU.

FUEL-CYCLE WORKING CAPITAL COST, C_c

The cost of fuel-cycle working capital is the cost of obtaining money to pay for fuel fabrication, fuel rental, spare fuel and other costs in connection with the fuel cycle which occur prior to the receipt of compensating revenues. In estimating fuel-cycle working capital costs it has been assumed that annual cost is 9 percent of the average

working capital required and that the capital required is the equivalent of the fuel fabrication cost of the first core.

While the preceding assumptions are very approximate, further refinements are believed unjustified for the purposes of this report. This is because of uncertainties as to the relative processing and fuel operating times, actual practice concerning when payments will be made for fuel processing, variation of fuel processing costs with time, possible differences in the way money is obtained and variations in interest rates and taxes. Estimates on a refined basis for the plants considered in this report have not yet been developed by their owners.

Other bases for computing working capital requirements have been considered and typical calculations carried out. As a result it appears that the assumptions used in this report are probably conservative in all cases where the fuel residence time in the reactor is a year or more. This is illustrated in Chart XIII, which compares a typical estimate of fuel-cycle working capital required with the nominal one based on the ground rules of this report.

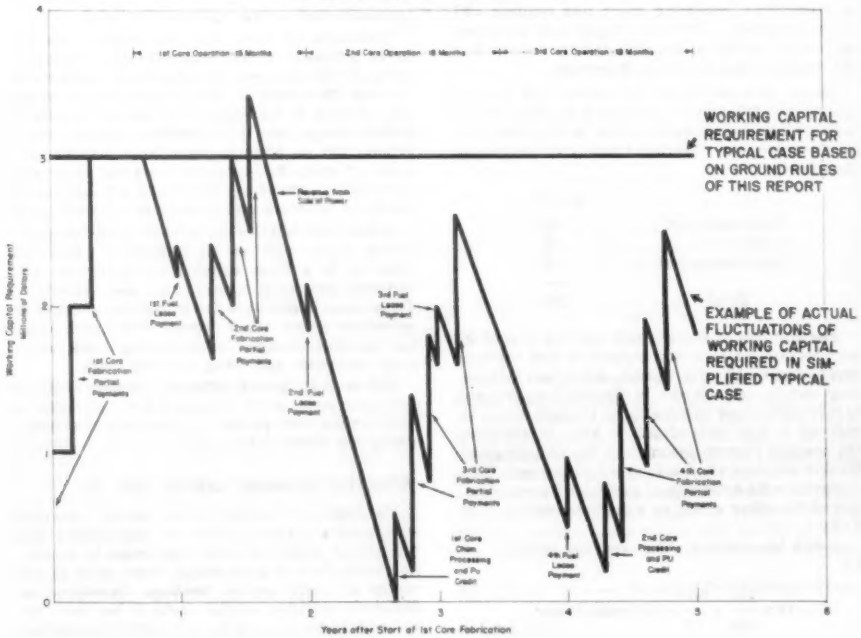
For the reasons discussed previously, uncertainties in fuel-cycle working capital cost for each case considered are large and variable. They range from +100, −65 percent, in one case, to ±40 percent in another.

FUEL MATERIAL LEASE COST, C_f

Fuel material lease cost is the annual interest paid on the value of enriched uranium fuel material obtained from and owned by the AEC. The values of enriched and depleted uranium assumed in computing this cost are as published by the AEC. The cost of using enriched fuel is taken to be 4 percent per annum of the fresh fuel value, in accordance with current AEC regulations. It is assumed that lease charges are paid on the initial

Chart XIII

FUEL CYCLE WORKING CAPITAL REQUIRED FOR TYPICAL CASE


WORKING CAPITAL REQUIREMENT FOR TYPICAL CASE BASED ON GROUND RULES OF THIS REPORT
EXAMPLE OF ACTUAL FLUCTUATIONS OF WORKING CAPITAL REQUIRED IN SIMPLIFIED TYPICAL CASE
Working Capital Requirement Millions of Dollars
Years after Start of 1st Core Fabrication
0
1
2
3
4
5
6

value of fuel material obtained from the AEC for the entire period during which it is outside AEC jurisdiction. Detailed assumptions are given in the Appendix.

It is possible that payment or credit for change in net fuel material value might be given at intervals during fuel use, with consequent changes in the value basis on which lease charges are computed. If so, lease costs for some types of reactors would be significantly changed and requirements for working capital would be affected to some extent.

Uncertainties in fuel lease costs arise because of possible variations in estimated fuel processing and reactor residence times and possible changes in policies as to when payments to the AEC for depletion of enriched fuel will be made. Changes in AEC schedules of value and the current AEC interest rate are not taken into account in the uncertainty analysis. They are assumed to be firm.

COST OF REPLACEABLE CORE CONTROLS AND STRUCTURES, C_r

Active control and poison rod sections, control rod shrouds, neutron sources, internal core instrumentation, fuel channels and other miscellaneous items, which are located directly in or adjacent to the fuel and which are intimately concerned with supporting it, measuring its performance or controlling its operation, will have to be removed and/or replaced from time to time due to radiation damage, depletion, corrosion or replacement of the fuel. Since these items are associated with fuel handling, their costs have been included in fuel costs in this report.

When possible, the costs of such replacements have been estimated on the basis of designers' judgments as to their useful lifetime and on their estimated or actual costs. In all cases their costs are highly uncertain but small — less than 4 percent of total costs.

Appendix

Basis for Economic Analysis of Nuclear Power Reactor Fuel Costs

Assumptions underlying estimates of nuclear fuel costs are set forth in this Appendix. Total fuel costs and uncertainties are discussed first; then assumptions for burnup, net station efficiency and nuclear fuel heat value are described. Finally, each element of fuel cost, such as fuel fabrication and recovery, is discussed. All of the cost estimates are based on "1958 dollars."

TOTAL UNIT FUEL COST

The total unit cost of electric energy attributable to fuel has been divided into the following elements of cost, described under similarly titled subsections in this Appendix:

Net fuel material costs,
Fuel fabrication costs,
Spent fuel processing costs,
Fuel cycle working capital costs,
Fuel material lease costs and
Cost of replaceable core controls and structures.

The average cost per kilogram of fuel passing through the reactor was obtained for each of these elements of cost. This cost was then divided by the average net electric energy produced per kilogram by use of the following relationship:

$$M \text{ (mills/ekwhr)} = \frac{C}{EKBX} = \frac{C}{2.2BX}$$

where: C = \$/kg of uranium charged into the reactor,
$E = 2.2 \times 10^7$ tkwhr/kg of fuel atoms fissioned (equivalent to about 3.4×10^{10} Btu/lb or 833,000 tmwd/short ton of atoms fissioned),
$K = 10^{-7}$ (a factor to convert to consistent units),
B = percent of burnup of heavy atoms in the fuel,
X = percent net station efficiency.

Estimates of burnup, net station efficiency and the average cost per kilogram are based on data provided by the reactor manufacturers and operators directly concerned.

The simplified sample fuel cost estimate which follows illustrates the method used. The actual estimates are much more complicated, involving

fuel material balance and flow sheets (like Chart IX), more detailed analysis of each cost element and, in some instances, separate treatment for several types of fuel in one reactor.

Sample Fuel Cost Estimate For Uniform Slightly Enriched UO_2 Power Reactor Core (Simplified for Illustration)

Reactor Characteristics

a. Core content: 30,000 kgU, fresh fuel
b. Rated net reactor power: 500 tmw
c. Rated net station power: 130 emw
d. Plant utilization factor: $Y = 0.7$
e. Specific power:
$$S = \frac{500{,}000 \text{ tkw}}{30{,}000 \text{ kgU}} = 16.67 \text{ tkw/kgU}$$
f. Net station efficiency: $X = \frac{130}{500} \times 100\% = 26\%$
g. Heat value of nuclear fuel: $E = 2.2 \times 10^7$ tkwhr per kg of fission products
h. Average fuel burnup:
$B = 300$ kg fission products/core
$$= \frac{300 \times 100\%}{30{,}000} = 1\% = 8330 \text{ tmwd/short ton}$$
i. Average plutonium content of spent fuel:
$$= \frac{120 \text{ kgPu}}{30{,}000 \text{ kgU}} \times 100\% = 0.4\%$$

Economic Assumptions

a. "Value" of uranium is taken to be that stated for U in UF_6 according to current AEC schedules.
b. Spent fuel recovery costs and costs for converting recovered uranium to UF_6 and recovered Pu to metal are estimated in accordance with current AEC schedules.
c. Value of Pu is \$30/kgPu in metal form.

	C (\$/kgU put into reactor)
1. *Net Fuel Material Cost, C_m*	
a. C'_U, value of U required for fresh fuel at 2.5% U-235 enrichment, assuming 3% processing losses: $C'_U = \frac{\$297}{\text{kgU}} \times \frac{1.03 \text{ kgU required}}{\text{kgU input}}$	= 306
b. C''_U, value of U recovered from spent fuel at 1.5% enrichment, assuming 2% processing losses and 1% destroyed in reactor: $C''_U = \frac{\$145.50}{\text{kgU}} \times \frac{0.97 \text{ kgU recovered}}{\text{kgU input}}$	= 141
c. Net U cost, C_U, is the value of U required minus value of U recovered: $C_U = (C'_U - C''_U)$	= 165
d. Credit for Pu recovered, C_{Pu}, assuming 1% losses in processing: $C_{Pu} = \frac{0.004 \text{ kgPu in spent fuel}}{\text{kgU input}} \times \frac{\$30{,}000}{\text{kgPu recovered}} \times \frac{0.99 \text{ kgPu recovered}}{\text{kgPu in spent fuel}}$	= 119
e. Net fuel material cost, C_m: $C_m = C_U - C_{Pu}$	= 46
2. *Fuel Fabrication Cost, C_f*	
a. Cost of converting UF_6 to UO_2 (including scrap recovery), C_{f-1}: $C_{f-1} = \frac{\$29.1}{\text{kgU processed}} \times \frac{1.03 \text{ kgU processed}}{\text{kgU input}}$	= 30
b. Cost of making UO_2 pellets (including scrap recovery), C_{f-2}: $C_{f-2} = \frac{\$39.2}{\text{kgU processed}} \times \frac{1.02 \text{ kgU processed}}{\text{kgU input}}$	= 40
c. Fabrication (including scrap recovery), C_{f-3}:	= 110
d. Shipping fresh fuel and fuel material, C_{f-4}: $C_{f-4} = \frac{\$60{,}000}{30{,}000 \text{ kgU input}}$	= 2
e. Total fuel fabrication cost, C_f	= 182
3. *Spent Fuel Processing Cost, C_p*	
a. Cost of shipping spent fuel and recovered and converted materials, C_{p-1}: $C_{p-1} = \frac{\$129{,}000}{30{,}000 \text{ kgU input}}$	= 4.3
b. Cost of recovery of pure U and Pu nitrates from spent UO_2, C_{p-2}: Recovery plant costs: \$15,300/day Recovery plant capacity: 1000 kg U/day Processing time: $30{,}000 \text{ kgU input} \times \frac{0.99 \text{ kgU processed}}{\text{kgU input}} \times \frac{1 \text{ day}}{1000 \text{ kgU processed}} = 29.7 \text{ days}$	

C ($/kgU put into reactor)

Plant cleanup time = 8 days
Processing cost, C_{p-2}:

$$C_{p-2} = \frac{\$15{,}300/\text{day} \times (29.7 + 8)\ \text{days}}{30{,}000\ \text{kgU input}} = 19.2$$

c. Conversion of pure uranium nitrate to UF_6, C_{p-3}:

$$C_{p-3} = \frac{\$5.6}{\text{kgU processed}} \times \frac{0.98\ \text{kg processed}}{\text{kgU input}} = 5.5$$

d. Conversion of pure Pu nitrate to Pu metal, C_{p-4}:

$$C_{p-4} = \frac{120\ \text{kgPu processed}}{30{,}000\ \text{kgU input}} \times \frac{\$1500}{\text{kgPu processed}} = 6$$

e. Recovery of Pu and U scrap, C_{p-5} = 5

f. Total spent fuel processing cost, C_p = 40.0

4. *Fuel Cycle Working Capital Costs, C_c*

a. The average working capital fund required is assumed to be the fuel fabrication cost, plus the cost of purchased U, if any, or:

$$\frac{\$182}{\text{kgU input}} \times 30{,}000\ \text{kgU input} = \$5{,}460{,}000$$

b. The average term of the working capital fund is the average time from payment of prepaid costs to receipt of compensating revenues. It is assumed to be the average residence time of fuel in the reactor, T_r (years).

$$T_r = \frac{25.2B}{SY} = \frac{25.2 \times 1}{0.7 \times 16.67} = 2.17\ \text{years}$$

c. Cost of the working capital fund, C_c, is assumed to be 9% simple interest per fund dollar per year.

$$C_c = \frac{\$5{,}460{,}000 \times 0.09 \times 2.17\ \text{years}}{30{,}000\ \text{kgU input}} = 35.5$$

5. *Fuel Material Lease Charge, C_l*

a. Value of uranium material leased:
$C'_U = \$306$/kgU

b. Term of lease, years:

Fresh fuel processing, T_f	= 0.7
Residence in reactor, T_r	= 2.17
Spent fuel processing, T_s	= 0.9
Term of lease, T_l	= 3.77 years

C ($/kgU put into reactor)

c. Cost of leasing material is 4% per year of material value:
$C_l = 0.04\,C'_U T_l = 0.04\,C'_U\,(T_f + T_r + T_s)$

$$= \frac{\$306}{\text{kgU input}} \times 3.77\ \text{years} \times \frac{\$0.04}{\$\text{yr}} = 46$$

6. *Cost of Replaceable Core Structures and Controls, C_r*

a. Control rods replaced per core	= $30,000
b. Internal instruments replaced per core	= 20,000
c. New core fastenings per core	= 10,000
	$60,000

d. $C_r = \frac{\$60{,}000/\text{core}}{30{,}000\ \text{kgU/core}} = 2$

7. *Total Cost, C_t*

C_U, Net uranium cost	= 165
C_{Pu}, Credit for Pu recovered	= 119
C_m, Net fuel material cost	= 46
C_f, Fuel fabrication cost	= 182
C_p, Spent fuel processing cost	= 40
C_c, Fuel cycle working capital cost	= 36
C_l, Fuel material lease charge	= 46
C_r, Cost of replaceable core controls and structures	= 2
C_t, Total unit fuel cost	= 352

8. *Cost, M (mills per ekwhr)*

a. $M = \frac{C}{EKBX}$

b. $EKBX = (2.2 \times 10^3) \times 10^{-7} \times 1 \times 26 = 57.2$

c. Therefore the cost of fuel in mills/ekwhr for each item of cost is the cost of that item in $/kg of U put into the reactor, divided by 57.2, or:

	M (mills/ekwhr)
$M_U = 165 \div 57.2$	= 2.89
$M_{Pu} = 119 \div 57.2$	= 2.08
$M_m = 46 \div 57.2$	= .81
$M_f = 182 \div 57.2$	= 3.18
$M_p = 40 \div 57.2$	= .70
$M_c = 36 \div 57.2$	= .63
$M_l = 46 \div 57.2$	= .81
$M_r = 2 \div 57.2$	= .03
$M_t = 352 \div 57.2$	= 6.16

UNCERTAINTIES IN FUEL COST ESTIMATES

Approximate uncertainties in fuel cost estimates were developed by obtaining estimates of the possible positive and negative variations in each variable on the right-hand side of the following expression for total fuel cost:

$$M_t\ (\text{mills/ekwhr}) = \frac{C_m + C_f + C_p + C_c + C_l + C_r}{EKBX} = \frac{C_t}{2.2BX}$$

where the symbols have the same meanings as in the immediately preceding sample fuel cost calculation. These possible variations were, in turn, obtained from estimates of subsidiary costs making up each variable.

A criterion for estimating possible variations was the requirement that there be only a 10 percent chance that these limits would be exceeded. This criterion could not be rigorously applied because no direct experimental evidence is yet available. Nevertheless, such a guideline was necessary.

In general, it would be expected that the uncertainty in a component cost would be calculated from the uncertainties in the terms making up the component by the use of elementary statistical theory. However, the elementary theory is based on the concept that the variations from the most probable value of a quantity are random and are symmetrically distributed about this central value.

However, the condition of symmetry does not hold for the estimates of several important elements of cost. Therefore an exact statistical calculation of the resultant uncertainty would require a detailed investigation into the nature of this unsymmetrical variation. Such an examination is not believed to be worth while, or even possible, at this stage.

Instead, the uncertainty was approximated by deriving a "normalized cost" for each item, so that the variations above and below this "normal" are equal. For example, if the estimate for C_p is \$20/kg +\$10/kg or −\$6/kg, the normalized estimate is \$22/kg ±\$8/kg. The corresponding "normalized uncertainty," ±\$8/kg, is then assumed to be symmetrical about \$22/kg.

Normalized estimates and corresponding normalized uncertainties were calculated for each term in the numerator of the preceding equation. The actual and the normalized estimates were added to obtain a normalized C_t and an actual C_t. The square root of the sum of the squares of all the normalized uncertainties was then taken to derive the combined normalized uncertainty in the normalized C_t. The range of C_t was then computed from the normalized C_t and its uncertainties.

For example, if normalized C_t is \$300/kg ±\$60/kg, the range of C_t is \$240/kg to \$360/kg. Uncertainty in the actual C_t is then estimated from these ranges. That is, if the actual C_t was \$320/kg, then the uncertainty about it derived from the above range is $+\frac{40}{320} = +12.5\%$

$$-\frac{80}{320} = -25\%.$$

In estimating the effect of uncertainty in burnup on the uncertainty in unit costs, M_t, the effect of changes in B on fuel material lease cost, C_l, fuel cycle working capital cost, C_c, and net fuel material cost, C_m, has to be taken into account. This is necessary for C_l and C_c because the average fuel residence time in the reactor, T_r, is a direct function of burnup, and C_l and C_c are functions of T_r. Similarly, the Pu and U-235 content of spent fuel—and, therefore, the net fuel material cost—depend on burnup.

After the percent uncertainties in each of the factors C_t, B, E and X were estimated, the percent effect on M_t of each uncertainty was found. For example, if the uncertainty in X is ±10 percent, the percent effect on M_t is

$$\left(\frac{1}{1.10} - 1\right) 100\% = -9\%, \text{ and}$$

$$\left(\frac{1}{0.90} - 1\right) 100\% = +11\%.$$

All of the positive percentages derived in this way were then combined by taking the square root of the sum of their squares to estimate the positive uncertainty in M_t. The negative uncertainty was similarly estimated.

AVERAGE PERCENT OF FUEL FISSIONED, B

Burnup is the average weight percent of fuel atoms fissioned in one fuel cycle. Fuel atoms in this definition include only atoms of thorium, uranium or plutonium.

Estimates of average attainable burnup for the initial three years of operation of the plants dealt with in this report were obtained from reactor designers. The basis for these estimates and their uncertainties were explored with the people directly involved.

Percent burnup is related to fuel residence time, T_r (years), specific power, S (tkw/kg of fuel atoms), and plant factor, Y (net ekwhr/yr ÷ 8760 × rated net ekw), in the following way:

$$B = \frac{YT_rS}{25.2}.$$

Burnup may be limited by depletion of nuclear reactivity or by mechanical failure due to such factors as corrosion, radiation effects, local overheating or vibration.

In cases where the loss of reactivity is expected to limit attainable burnup, it was assumed that the fuel was burned until there was no longer sufficient reactivity to override equilibrium fission product poison effect under rated operating conditions of temperature, pressure and power.

Limited experimental data on mechanical factors, such as in Table A-I, indicate that at exposures of 10,000 to 15,000 mwd/t, UO_2 and ThO_2

TABLE A-I—IRRADIATION DATA ON ZR-2-CLAD UO_2 FUEL ELEMENTS[1]

Heat Flux (Btu/ft²hr × 10⁻³)	Metal Burnup (%)	Calculated Central Temperature (deg. C)	Original Specimen Dimensions: UO_2 Diameter (in.)	Clearance: Diameter (in.)	Clearance: Axial (in.)	Tube O.D. (in.)	Total Length (in.)	Changes in Specimens: Diameter (in.)	Changes in Specimens: Length (in.)	Molten Zone Diameter (in.)	Gas Release (% Kr-85 Formed)
370	1.42	2650	0.3445	0.0015	0	0.402	5.237	0	0	0	5.0
420	1.76	>2750	.3445	.0015	0	.400	5.240	0	0	0	8.1
300	0.89	2200	.3445	.0015	0	.402	5.238	0	0	0	—
330[2]	1.82	2400	.3445	.002	0.080	.414	5.205	0	0	0	Lost
540[2]	2.86	>2750	.3445	.002	0.080	.414	5.222	+0.012	0	0.200	Lost
600[2]	3.24	>2750	.3445	.002	0.080	.414	5.224	+0.015	0	0.230	Lost
300[2]	1.56	2200	.3445	.002	0.080	.414	5.206	0	0	0	Lost
300	0.84	1400	.3570	.002	0	.413	4.544	0	0	0	0.25
900	1.61	>2750	.3570	.002	0	.413	*4.560	+0.009	+0.009	0.250	13.6
890	1.57	>2750	.3570	.002	0	.413	4.506	+0.008	+0.015	0.275	15.3
300	0.79	2200	.3570	.002	0	.413	4.518	0	0	0	—
340	0.87	2400	.3510	.008	0	.413		0		0	—
670	1.87	>2750	.3510	.008	0	.413		+0.002		0.290	—
840	2.02	>2750	.3510	.008	0	.413		+0.018		0.325	35.6
340	1.03	2400	.3510	.008	0	.413		0		0	1.2
450[3]	2.34		.357	.002	0.150	.414	10.298	0	0		
450[3]	2.34		.357	.002	0.058	.414	10.302	0	0		
450[3]	1.17		.355	.004	0.150	.414	10.303	0	0		
450[3]	1.17		.355	.004	0.055	.414	10.297	0	0		

[1] *Technical Progress Review, Power Reactor Technology*, Vol. 1, No. 3, p. 30.

[2] Temperature cycled 7000 times.

[3] The Zircalcy-2 tubing for these rods was machined from bar stock, rather than extruded, as is the case for the PWR rods, and this machined tubing was of somewhat dubious quality. The cladding split on all the rods.

fuels clad in zircaloy 2 or stainless steel have no inherent tendency to fail in environments such as those planned for the Rowe, Dresden and Indian Point stations. While there is not sufficient information on the specific fuels involved to be sure, it does not appear that uncertainties in mechanical limitation on burnup are as great as those introduced by probable errors in predicting reactivity limits on burnup. Therefore, for the water-cooled, oxide-fueled reactors, uncertainties in burnup are taken to be equivalent to those due to uncertainties in burnup as limited by reactivity.

TABLE A-II

Source of Energy	(1) Total Energy (mev/U-235 fission)	(2) Assumed Average Heat Release in Reactor Core (mev/fission)
Instantaneous		
Fission fragments	168 ±5	168 ±10
Fission neutrons	5 ±0.5	5 ± 0.5
Fission γ rays	5 ±1	5 ± 1
Fission neutrinos	10	0
Captured γ rays	..	5 ± 4
Delayed		
β decay of fission products	7 ±1	6.5 ± 1
γ decay of fission products	6 ±1	5.5 ± 1
Decay of products of neutron capture	..	1 ± 1
Total	201 ±5	196 ±11

HEAT VALUE OF NUCLEAR FUEL, *E*

In this report the heat value of nuclear fuel, E, is assumed to be 2.2×10^7 tkwhr/kg of fuel fissioned. The basic information from which this heat value is derived is incorporated in Table A-II, which gives an estimate of average fission energy for U-235 and the assumed average heat release per fission in the cores of reactors dealt with in this report.

In deriving an average heat release in the reactor (196 mev/fission), and the associated heat value for nuclear fuel (2.2×10^7 tkwhr/kg of fuel fissioned), the following assumptions have been made:

1. Energy released in all types of fission is the same as that from the thermal neutron fission of U-235.
2. All instantaneous fission energy except that in neutrinos becomes heat in the reactor core, thermal shields or fertile blankets.
3. About 87 percent of the energy from decay of radioactive products formed by fission or activation becomes heat in the reactor core.
4. Of the total heat release in the core, about 3 percent is from the nonfission capture of neutrons in U-238, other fertile materials, structural materials and coolant.

The effective heat value for a specific reactor at a particular time may vary from the assumed

value and introduce uncertainties of the magnitude indicated in column 2 of Table A-II. These uncertainties are due to probable errors in the basic experimental measurements and calculation of fission energy release, and to one or more of the following reasons:

1. Plutonium fission, which contributes a significant fraction of total energy in many reactors (see Chart XI), is more energetic than U-235 fission. Fission energy of U-233, U-238 and other isotopes is also different from the U-235 value measured.
2. Depending on reactor configuration and materials, a varying portion of the gamma rays and neutrons created in the core may escape and release their energy elsewhere than in the reactor core. In most cases this effect is small.
3. The fraction of energy from decay of fission products released in the reactor will vary, depending on the length of time the fuel is in the reactor. Also, fresh fuel will generate less energy from fission product decay than highly irradiated fuel.
4. The amount of energy in gamma rays created in the core because of neutrons captured in fertile, structural and coolant materials varies greatly from one type of reactor to another, depending on the kind of materials, the neutron energy spectrum and how the coolant is circulated.

In view of these factors, it has been assumed for all of the purposes of this report that the uncertainty in the value, 2.2×10^7 tkwhr/kg of fuel fissioned, is ± 5 percent.

NET STATION EFFICIENCY, X

Net station efficiency, for the purposes of this report, is defined as the average electric energy (in ekwhr) transmitted from a station, divided by the nuclear thermal energy (in tkwhr) from which it is derived, for the initial three years of station operation.

The net station efficiency assumed for each case was that recommended by the station designers for operation at rated power.

When stations are initially started up, the net station efficiency may tend to be low if the equipment is operated below rated capacity. On the other hand, during initial operation the condensers and exchangers will be clean, which is an offsetting factor.

In the case of stations, such as Indian Point, where part of the thermal energy is from nuclear heat and part from other sources, such as an oil-fired superheater, the net station efficiency assumed to apply to the nuclear fuel cost is a hypothetical one analogous to that which could be obtained with the type of nuclear plant involved at the temperatures and pressures of its operation.

NET FUEL MATERIAL COSTS, C_m

The net fuel material cost is assumed to be the cost or value of fissionable and fertile materials procured, minus the value of the same materials (depleted and/or increased by irradiation and processing) as sold, re-used, returned for credit or otherwise disposed of. Chart IX in the body of this report illustrates for a particular case the various input and output streams of fuel material which have to be accounted for in estimating net fuel material costs.

Net fuel material costs have been developed on the following basis:

1. The value of enriched uranium and the cost of depleted uranium are as given in the AEC price schedules current as of the date of this report.
2. The cost of natural uranium in the form of mill product or highly purified U_3O_8 is taken at the current market prices.
3. The cost of highly purified ThO_2 is \$15/kg of contained thorium. This is based on quotations by a chemical company which produces ThO_2.
4. The values of the various mixtures of U-235 and U-233 are in accordance with current AEC schedules.
5. The value of purified plutonium metal buttons is \$12,000/kg or \$30,000/kg of plutonium as noted.
6. The percentage of fuel material lost or scrapped in fuel processing varies with the specific design of the fuel, the manufacturer, specifications and inspection procedures. In all cases losses in spent fuel recovery are assumed to be 1 percent of input for plutonium, uranium and thorium.
7. It is assumed that enriched and depleted uranium are obtained from the AEC and that thorium and natural uranium are procured on the open market.
8. It is assumed that spent enriched fuel will be recovered and recycled or sent to the AEC for credit only if the value of the recovered products exceeds the cost of recovery. If the value does not exceed the recovery cost, it is assumed that the used fuel is returned to the AEC for storage, without credit. If leased fuel is left unrecovered, it is assumed that the leasor pays the AEC for the outstanding value of the unrecovered fuel and that no further

lease charges will be incurred. Storage or disposal costs are included in spent fuel processing costs, C_p.

9. Credit for spent thorium and natural and depleted uranium is based on the assumption that they will be recovered from spent fuel and disposed of at current prices, provided their value in recovered form exceeds the cost of processing. If it does not, it is assumed they are stored or disposed of with an appropriate cost for storage or disposal. Spent fuel recovery, processing, storage and/or disposal costs are included in spent fuel processing costs, C_p.

10. Zirconium and other fuel cladding and structural material will not be recovered from spent fuel, and no credit or revenue are included for recovery of any materials other than fissionable and fertile materials.

Factors which determine net fuel material cost, C_m, are:

1. The reduction in U-235 concentration in uranium with burnup and the related depletion of uranium value;
2. The fraction of energy from U-235 fissioned;
3. The fraction of energy from fission of U-238 and its derivatives (such as plutonium);
4. The value of plutonium in spent fuel; and
5. Losses of fuel material during processing.

The interrelation between these factors can be illustrated by an example. If it is assumed that 2.5-percent-enriched uranium fuel leased under present AEC schedules is put into a thermal reactor operating at 25 percent net station efficiency, X, and that 6000 tmwd/t are generated from U-235 before the fuel is discharged, then the basic depletion cost of the nuclear fuel, obtained from Chart X, is 3.3 mills/ekwhr.

From information such as that in Chart XI it might then be estimated that when 6000 tmwd/t have been generated from U-235, 2330 tmwd/t have been generated from fertile material, for a total of 8330 tmwd/t. The basic depletion cost would then be reduced to:

$$3.3 \times \frac{6000}{8330} = 2.4 \text{ mills/ekwhr}$$

Burnup, B, at 8330 tmwd/t, is about 1 percent. From Chart XII it can be seen that at this burnup, spent fuel might contain about 0.5 percent plutonium by weight. If plutonium is valued at $12,000/kg, then the plutonium value in spent fuel would be $60/kg. From the expression

$$M \text{ (mills/ekwhr)} = \frac{C}{2.2BX}$$

the reduction in net fuel material cost, M_m, due to credit for plutonium in spent fuel in this case is

$$M_{P_u} = \frac{C_{P_u}}{2.2BX} = \frac{60}{2.2 \times 1 \times 25} = 1.1$$

This reduces the 2.4 mills/ekwhr derived before to 1.3.

Irrecoverable fuel material losses in processing will increase the 1.3 mills/ekwhr derived previously. If they are assumed to amount to $30/kg of fuel material, including plutonium losses, this is seen by analogy to the plutonium credit derivation immediately preceding to be 0.5 mills/ekwhr. Addition of this cost to the 1.3 mills/ekwhr previously derived gives a net fuel material cost, C_m, for the sample case of 1.8 mills/ekwhr.

Net station efficiency also has an effect on net fuel material cost. If in the previous example it had been 28 percent instead of 25 percent, the 1.8 mills/ekwhr derived would be

$$1.8 \times \frac{25}{28} = 1.6 \text{ mills/ekwhr.}$$

FUEL FABRICATION COST, C_f

Information on fuel fabrication cost, obtained directly from the fuel manufacturers or plant owners for all the cases covered in this report, is based on actual experience in only a few cases. In developing these estimates and evaluating them for uncertainties, account has been taken of:

1. Cost experience records for a few available cases, such as Shippingport;
2. Firm proposals from fuel manufacturers covering most of the major fabrication steps;
3. Estimates for specific reactors made by fuel processors and fuel manufacturers;
4. Estimates of the unit cost of processing or fabrication made by fuel processors and manufacturers; and
5. Cost experience in the manufacture of plutonium production reactor fuels.

Fuel fabrication cost is the cost of all steps necessary to convert fissionable and fertile fuel material as procured from the AEC or the ore processors into finished and accepted fuel. The condition in which the fuel material enters the fuel processing cycle and the steps necessary in one mode of operation are indicated in steps 1 through 6 of Chart IX.

Fuel fabrication cost includes the following types of processes and charges:

1. Conversion of enriched or depleted uranium from UF_6 to UO_2 and/or processing of recycled, enriched or depleted uranium compounds to re-enrich them by blending, and to convert them to UO_2;
2. Conversion of natural uranium from U_3O_8 mill product to UO_2, or thorium mill product to ThO_2, if natural uranium or thorium are to be used in the reactor as dioxides;
3. Preparation, compaction and sintering of UO_2 powder or ThO_2-UO_2 powder mixtures, into fuel pellets;
4. Conversion of enriched UF_6, depleted UF_6, natural uranium U_3O_8 mill product, or thorium mill product compounds to metal or metallic alloys ready for assembly into fuel elements;
5. Grinding of UO_2 or UO_2-ThO_2 pellets;
6. Manufacture and/or preparation of fuel cladding and structural parts of fuel elements;
7. Assembly of fuel material with the fuel cladding and structural fuel element parts;
8. Packaging and shipping of all materials, including fissionable and fertile materials, cladding materials, structural parts, processed materials and finished fuel;
9. Reprocessing all scrap material and other materials from fuel fabrication into form suitable for re-use, sale, credit or disposal (including, for example, the recovery of scrap zirconium if it is recovered);
10. All inspection, analysis, material accounting, control and identification, and other supporting functions carried out, except those done by reactor operators;
11. Normal amortization of fuel fabrication and inspection equipment and buildings, profit and taxes, administrative and other overhead, including that connected with obtaining licenses for fuel fabrication;
12. Fuel cladding material, structural parts of the fuel element (including process materials, and the net cost of rejected, scrapped and lost materials of this type);
13. Insurance required in connection with fuel fabrication, including that connected with the handling of fissionable, fertile and other radioactive materials.

Fuel fabrication costs are based on the assumption that the batches of fuel processed are the same size as the fuel batches loaded in the reactor, except for those reactors with frequent loading, such as the Enrico Fermi plant.

The following cost elements are excluded from fuel fabrication costs:

1. Fissionable and fertile materials, including losses, which are included in net fuel material costs, C_m;
2. Fabrication of initial spare fuel element inventory, accounted for in fuel cycle working capital costs, C_c;
3. Inspection of fuel by reactor operators at the reactor site;
4. Fuel material lease cost and fuel cycle working capital cost incurred in connection with fuel fabrication, which are included in the items C_l and C_c.

SPENT FUEL PROCESSING COST, C_p

Estimates of the cost of recovering spent fuel are based on the AEC cost schedules published in the *Federal Register*, March 12, 1957, and March 12, 1958, and on extrapolation of specific experience reported in various AEC plants.

Spent fuel processing costs are estimated as follows:

1. Processing spent fuel to pure uranium, thorium and/or plutonium nitrate forms

$$= \$15{,}300 \left(\frac{a}{b} + c \right)$$

where: a = Weight in kg of uranium and/or thorium in fuel elements to be reprocessed as a batch, assuming that the batches processed through spent fuel recovery are the same size as the fuel batches discharged from the reactors, except for those reactors with frequent loading such as the Enrico Fermi plant.

b = Reprocessing rate in kg per day. (The rate for a specific fuel element must be obtained from the AEC. For rough estimating purposes the rate may be computed as: $b = \frac{4000}{\%\ \text{enrichment}}$, not to exceed 1000 kg per day.)

c = "Turnaround" time — startup and cleanup time in days, equal to $\frac{a}{b}$,

unless $\frac{a}{b}$ is less than three or more than eight, in which case c is three or eight, respectively.

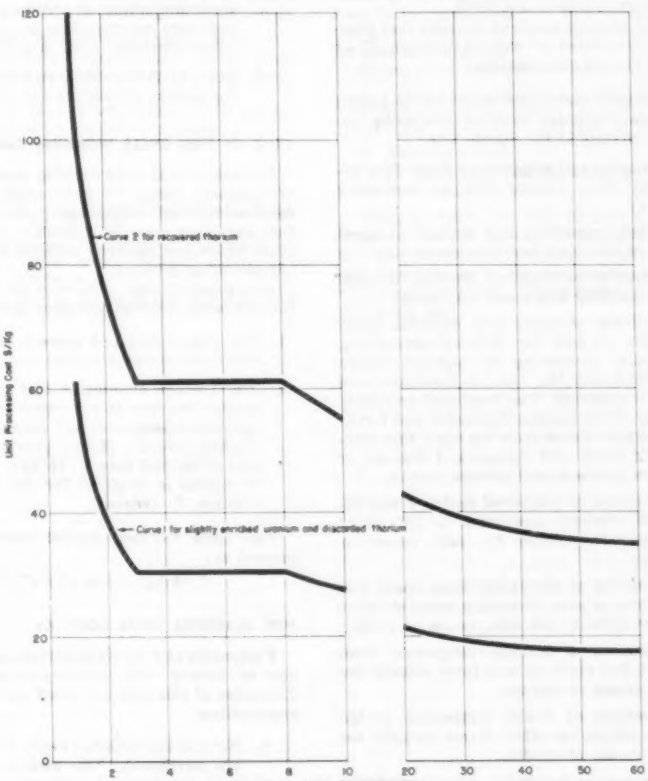
2. Converting recovered pure uranium nitrate, less than 5 percent enriched, to UF_6—$5.60/kg of contained uranium—and for uranium more than 5 percent enriched—$32/kg of uranium.
3. Converting recovered pure plutonium nitrate to plutonium metal—$1500/kg of contained plutonium.
4. Processing thorium fuels is the same as for uranium fuels, as in item 1, if the thorium is discarded. If it is recovered, the costs are double.

Chart A-I gives the spent fuel recovery cost as a function of batch size for slightly enriched

Chart A-1

SPENT FUEL RECOVERY COST

For Converting Spent Fissionable & Fertile Material to Purified Nitrates[1]



(1) Based on AEC processing schedules without escalation as used for negotiation by AEC. Variation in cladding, fuel composition and other factors will materially affect these costs

uranium and thorium derived on the preceding basis.

Spent fuel processing costs include all costs necessary to convert the fissionable and fertile materials in spent fuel elements to a form suitable for re-use, sale, credit or disposal. In cases where the value of recovered materials is less than the cost of recovering them, it is assumed the materials are stored.

The cost of processing steps comprises the costs of process materials, plant operation, inspection, analysis, material accounting and identification, and other supporting functions. It also includes the cost of write-off of research and development, amortization of production and research and development facilities, licenses, taxes, insurance, administrative overhead and profit.

The types of steps involved in spent fuel processing are illustrated in steps 8 through 13 of Chart IX. Typical steps include:

1. Storage of discharged spent fuel to permit radioactive decay prior to processing, except storage at the reactor site;
2. Packaging and shipping of spent fuel elements from reactor site to processing plant;
3. Receipt, inspection and storage of spent fuel at the spent fuel processing site;
4. Mechanical or chemical removal of spent fuel cladding and structural parts;
5. Dissolving of spent fuel material, preparation of feed for chemical processing, chemical processing to separate fission products and the various fissionable and fertile materials, final treatment and packaging of the various fissionable and fertile materials effluent from the spent fuel processing plant, and storage and disposal of fission products and process wastes;
6. Conversion of recovered enriched and depleted uranium compounds to UF_6 or to compounds suitable for sale, re-use or credit;
7. Conversion of plutonium from spent fuel recovery to pure plutonium metal or other forms suitable for sale, re-use or credit;
8. Conversion of thorium compounds from spent fuel recovery to a form suitable for sale, re-use or storage;
9. Conversion of U-233 compounds to the pure nitrate or other forms suitable for sale, re-use or credit;
10. Reprocessing fissionable or fertile material scrap into a form suitable for re-use, sale, credit or disposal;
11. Storage of processed materials, and of fissionable and fertile materials awaiting processing, and of fission products and wastes, except storage at the reactor site.

Spent fuel recovery costs exclude the costs of:

1. Fissionable and fertile materials included in net fuel material costs, C_m;
2. Recovery of cladding and structural material from spent fuel on the assumption that they will not be recovered;
3. Handling and preparing spent fuel at the reactor site, such as might be involved in storage for decay of radioactivity, or partial mechanical disassembly of the fuel or decontamination of shipping casks. Such costs are considered to be included in reactor operating costs and fixed charges;
4. Lease of fuel material and fuel cycle working capital, included in the items so named.

COST OF FUEL CYCLE WORKING CAPITAL, C_c

The cost of fuel cycle working capital is the cost of obtaining money to make payments for fuel fabrication, fuel processing, fuel rental, spare fuel and other costs in connection with the fuel cycle which are incurred prior to the receipt of compensating revenue.

In estimating fuel cycle working capital costs, the following assumptions have been made:

1. The annual cost is 9 percent of the average fuel cycle working capital required.
2. The average amount of fuel cycle working capital required is equivalent to the cost of purchased fissionable and fertile material for the first core, C'_f (\$/kg), plus the fabrication cost of the first core, C_f (\$/kg). This amount of capital is required for the average core lifetime, T_r (years).

Fuel cycle working capital costs can be expressed as:

$$C_c\ (\$/\text{kg}) = 0.09\ (C_f + C'_f)\ T_r$$

FUEL MATERIAL LEASE COST, C_l

Fissionable and fertile material lease cost is the cost of leasing AEC-owned enriched uranium. Estimates of this cost are based on the following assumptions:

1. Natural and depleted uranium and thorium are purchased. The working capital for such purchases is included in fuel cycle working capital cost, C_c, and not under fuel material lease costs.

2. Enriched uranium is rented at a rate of 4 percent per annum of the initial fuel material value.
3. The value of enriched uranium is in accordance with the current AEC schedules of value.
4. The time during which interest is paid for enriched uranium in any batch begins at the time of initial shipment from the AEC and continues until the fuel is returned to the AEC for credit. This average time has been assumed to be the average residence time of the fuel in the reactor, T_r, plus the following:

For large water reactors:
Fresh fuel processing, $T_f = 0.7$ years
Spent fuel processing, $T_s = 0.9$ years

For the Enrico Fermi plant core:
Fresh fuel processing, $T_f = 0.3$ years
Spent fuel processing, $T_s = 0.7$ years

The average fuel residence time, T_r, in the reactor is estimated in the following way:

$$T_r = \frac{25.2B}{SY}$$

where: T_r = Average fuel residence time in the reactor, in years
B = Burnup (percent of fissionable and fertile atoms fissioned before fuel discharge)
S = Specific power at full power (tkw/kg of fresh fuel)
Y = Plant utilization factor (net ekwhr/yr ÷ 8760 × rated net ekw)

For large stations, the fuel material lease cost is assumed to be

$$C_l = 0.04\ (T_f + T_r + T_s)\ C'_U\ (\$/\text{kg})$$

where C'_U is the initial value of fissionable and fertile material leased and the other symbols are as previously described.

COST OF REPLACEABLE CORE CONTROLS AND STRUCTURES, C_r

The kinds of equipment included in this category are those which are located in or directly adjacent to the fuel and which are intimately concerned with supporting it, controlling its operation or measuring its performance, and which have to be replaced almost as frequently as fuel, due to replacement of the fuel or due to radiation damage or corrosion.

Examples of this kind of item are:

1. Control rod absorption or fuel sections
2. Poison rod absorption sections
3. Control or poison rod shrouds
4. Neutron sources
5. Internal core instrumentation
6. Fuel channels

When possible, the cost of core controls and structures which have to be replaced from time to time was approximated on the basis of designers' estimates as to the useful lifetime and cost of replaceable items. Uncertainties in these estimates are high.

APPENDIX 7

TECHNICAL INFORMATION PROGRAM OF THE U.S. ATOMIC ENERGY COMMISSION

CONGRESS OF THE UNITED STATES,
JOINT COMMITTEE ON ATOMIC ENERGY,
Washington, D.C., February 3, 1959.

Mr. A. R. LUEDECKE,
General Manager, Atomic Energy Commission,
Washington, D.C.

DEAR MR. LUEDECKE: By Mr. R. W. Cook's letter of February 14, 1958, the Joint Committee was furnished a comprehensive report on the Commission's program for gathering and disseminating information within the atomic energy program and among the scientific community and industry at large. The various activities and functions of the Commission's Division of Information Services were also indicated.

The committee would appreciate receiving an updated report of the Commission's information program summarizing key developments in the past year in major areas of interest. In particular, comment would be appreciated on the following topics:

1. Evaluation of quarterly technical progress reviews initiated during the past year in the distribution of technical data with respect to alleviating problems of scientists and engineers in keeping up with progress being made in important areas of nuclear development.

2. Review of the access-permit program and summation of applications, received and permits issued in 1958.

3. Number of declassified and new unclassified documents completed, together with any special declassification steps taken during 1958; number of technical documents generated and distributed by AEC and contractors, broken down into classified and unclassified listings in 1958.

4. Current listing of depository libraries, both classified and unclassified, with description of materials contained, and locations.

5. Status and availability of technical books sponsored by the Commission and a list of technical books being considered for fiscal year 1958.

6. Report on expanded translation program, including additional Russian monographs being translated in current fiscal year, outlay of translation program budget, and measures adopted to avoid duplication by coordination of translation efforts with other Federal agencies.

It is understood that the above list of topics may also be covered generally in the formal presentation of the Commission in the section 202 hearings. However, in keeping with the continuing interest of the committee in the information bases of the atomic energy industry and an active program of preparation and presentation of technical information, the additional report requested above will be most appreciated, and can be included in the record of the hearing.

Sincerely yours,

JAMES T. RAMEY, *Executive Director.*

U.S. ATOMIC ENERGY COMMISSION,
Washington, D.C., March 17, 1959.

Mr. JAMES T. RAMEY,
Executive Director, Joint Committee on Atomic Energy,
Congress of the United States.

DEAR MR. RAMEY: In response to your request of February 3, 1959, I am enclosing a report which summarizes key developments during the past year in the Commission's program for disseminating technical information to industry and the scientific community. The report covers the six topics listed in your letter and additional topics we feel will be of interest to the Joint Committee.

Sincerely yours,

A. R. LUEDECKE, *General Manager.*

TECHNICAL INFORMATION PROGRAM OF THE U.S. ATOMIC ENERGY COMMISSION—A SUMMARY OF KEY DEVELOPMENTS DURING 1958

Prepared for the Joint Committee on Atomic Energy,
Congress of the United States

FOREWORD

This report summarizes key developments in the U.S. Atomic Energy Commission's technical information program during 1958. Significant progress was made in all phases of the program: publication, declassification, and methods for making the growing body of atomic energy information more accessible and useful to industry and the scientific community.

As in the past, the Commission in planning its program sought advice from the Technical Information Panel and the Advisory Committee on Industrial Information. Both groups rendered valuable assistance.

I. ABSTRACT JOURNALS AND OTHER REFERENCE TOOLS

Nuclear Science Abstracts

This semimonthly abstract journal, published by the Commission since 1947, is recognized the world over as the key to the unclassified atomic energy literature. It is the only unclassified journal devoted solely to announcing and abstracting the literature of nuclear science and technology. Because nuclear specialists both within and outside the Government program depend heavily on Nuclear Science Abstracts, the Commission endeavors to make the coverage and indexing of the journal as comprehensive and useful as possible.

The growth of Nuclear Science Abstracts is a rough measure of the growth of nuclear enterprise in the United States and abroad. Nuclear Science Abstracts for 1958 contained almost 18,000 abstracts, approximately 4,500 more than for the previous year. The number for 1959 is expected to exceed 24,000. The sheer expansion of the domestic atomic energy literature accounts for most of this increase in the number of abstracts. There is, however, another important factor: The Commission is now obtaining and abstracting in the journal significant foreign literature previously not generally available in this country. Included in this literature are the official publications of countries with which the United States has formal agreements for cooperation. Also included are specialized journals, reports, and monographs obtained through more than 360 "quid pro quo" agreements with foreign universities, research institutions, and commercial organizations, many of which are in Soviet-bloc countries.

In the preparation of Nuclear Science Abstracts, increasing attention is being given to industrial literature, notably patents. Here too, agreements with foreign atomic energy establishments and patent offices are helping to provide prompt and comprehensive coverage.

The usefulness of any abstract journal depends on the rapidity with which indexes are cumulated and published. The Commission completed the groundwork in 1958 for using machine techniques in preparing indexes for Nuclear Science Abstracts. Each issue of Nuclear Science Abstracts now includes a complete subject index. Never before has an abstract-journal publisher been able to issue an index simultaneously with the abstracts themselves. The greatest advantage of the system, however, is that it permits the cumulation and publication of quarterly, semiannual, and annual indexes in a matter of 2 or 3 weeks rather than 2 or 3 months. Eliminating the long delay in publishing cumulative indexes will diminish the need for card catalogs at Commission facilities, thus resulting in substantial savings. Other U.S. abstracting services are studying the Commission's new system with a view to adopting it in their own operations.

Nuclear Science Abstracts is sold by the Superintendent of Documents, U.S. Government Printing Office. A 1-year subscription—24 issues and 4 cumulative indexes—sells for $33.

Classified abstract journals

The Commission's program for announcing classified reports in a series of abstract journals has been continued. Abstracts of Classified Reports, issued semimonthly, and Abstracts of Weapon-Test Reports, issued quarterly, are prepared to meet the needs of the Commission, its contractors, and other participating agencies. Confidential Reports for Civilian Applications and Secret Reports for Civilian Applications are special monthly abstract compilations designed to

serve firms, institutions, and individuals—access-permit holders—who have been granted access to restricted data for private purposes.

Bibliographies and literature searches

To facilitate the selection and location of literature pertaining to nuclear subjects of wide current interest, the Commission's Technical Information Service prepares and publishes bibliographies. In addition, it conducts literature searches in support of specific Government research programs. This literature search service is also available to access-permit holders and the general public at $6 an hour. In 1958 the Commission published 15 unclassified bibliographies and conducted 250 literature searches. Bibliographies published in 1958 are listed in appendix I–A. Unclassified bibliographies are distributed to all Commission depository libraries and are placed on sale at the Office of Technical Services, Department of Commerce. Bibliographies and literature searches covering classified subjects in the civilian applications program are sold to access-permit holders.

II. TECHNICAL PROGRESS REVIEWS

The quarterly technical progress reviews—Power Reactor Technology, Reactor Core Materials, and Reactor Fuel Processing—have now entered their second year of publication. The Commission feels that the reviews are serving the principal purpose for which they were initiated; namely, to help U.S. scientists and engineers stay abreast of important developments in key areas of nuclear science and technology. It also feels that the reviews are serving an important purpose in the foreign sector by providing our technical friends abroad with concise summaries of nuclear progress in the United States.

Total circulation of the reviews now exceeds 6,000 copies and is increasing at the rate of 1,200–1,500 copies each quarter. This rate will probably increase as more technical people become aware of the existence of the publications. Several professional societies ane helping the Commission to publicize the reviews by mailing descriptive fliers to their memberships. Cooperating societies include the American Society for Metals, American Nuclear Society, and American Institute of Chemical Engineers. Copies of the fliers being used to publicize the reviews are attached as appendix II–A.

To foster the widest possible dissemination of information contained in the reviews, the Commission, on request, provides trade and professional journal editors advance manuscript copy. This procedure gives the editors the opportunity to excerpt or digest material and publish it for their particular readerships while it is "fresh." Seventeen editors have asked to receive advance copy for one or more reviews.

The Commission plans to start a review on nuclear safety before the end of fiscal year 1959. Primary emphasis in this review will be on reactor safety; i.e., reactor kinetics and control, nonnuclear reactions that could lead to release of fission products (e.g., water-metal reactions), containment, and environmental factors. The review will also cover nuclear safety in fuel fabrication, fuel reprocessing, and other plant and laboratory activities in which a criticality incident might occur. Plans for starting this new review are contingent, of course, on approval of the Bureau of the Budget.

III. TECHNICAL BOOKS

Nineteen hundred and fifty-eight was a year of considerable accomplishment in the Commission's program for providing handbooks, monographs, and other texts needed by scientists, engineers, and management people to advance nuclear enterprise at home and abroad. During the year the Commission published 18 books and started 10 new books. Twelve Commission-sponsored [1] volumes were presented at Geneva last September as part of the U.S. contribution to the Second International Conference on the Peaceful Uses of Atomic Energy.

Books published by the Commission during 1958 are listed in appendix III–A. Twenty-seven books in press or in preparation as of February 10, 1959, are listed in appendix III–B. Appendix III–C is a list of titles for prospective books from which a total of eight titles will be selected for contracting in fiscal year 1959. Two titles already contracted for this fiscal year are so identified in the list.

[1] The U.S. presentation included two aditional volumes prepared under private auspices.

Supplementing the technical book program is the Commission's program for publishing collections of papers presented at technical meetings and symposia. Appendix III–D lists proceedings published by the Commission in 1958 and placed on sale at the Office of Technical Services, Department of Commerce.

IV. TRANSLATIONS

During 1958 the Commission continued to be the principal source of English translations of important atomic energy literature published in other languages. More than half of the 861 translations announced in Nuclear Science Abstracts in the course of the year were produced directly or indirectly under Commission sponsorship. As in the past, heavy emphasis was on translation of Russian publications.

Commission contractors, particularly those operating major plants and laboratories, translate substantial numbers of foreign journal articles to meet the specific needs of their scientists and engineers. The Comission in its contract translations program concentrates on monographs of broad interest to technical people both within and outside the Government program. Titles of 16 monographs published under this program last year are listed in appendix IV–A.

All translations produced by the Commission and its contractors are promptly announced in Nuclear Science Abstracts and placed on sale at the Office of Technical Services, Department of Commerce. Photocopies may be obtained from the Library of Congress. Reference copies are placed in Commission depository libraries and in the Special Libraries Association translation pool maintained at the John Crerar Library, Chicago, Ill.

In fiscal year 1959 a total of $40,000 is being used by the Commission for the translation of monographs. Translation of foreign journals previously financed partly by the Commission is continuing under sponsorship of the National Science Foundation. Besides supporting the translation of current issues of the journals, the National Science Foundation is making arrangements, at the Commission's request, to translate back issues with counterpart funds.

The Commission works closely with other Federal agencies to coordinate its translation activities with theirs. All titles proposed for translation by the Commission or its contractors are carefully checked against the master list maintained by the Central Intelligence Agency and the newly established file of the Office of Technical Services to assure that translations have not already been made or are underway. The Commission also prepares periodically lists of titles being translated under its auspices and under those of its contractors and cooperating agencies, including the United Kingdom atomic energy establishments. These lists, which are distributed to the Office of Technical Services, Central Intelligence Agency, and participating organizations, not only help prevent duplication of translation effort but also serve to announce the availability of translations completed.

Although the present emphasis, quite properly, is on translating Russian technical publications, there are definite indications that systematic translation of atomic energy literature published in other languages would be very worthwhile. First-rate articles and monographs are being published, for example, in Japanese, Chinese, and Czechoslovakian, which can be read by only a handful of U.S. scientists. The Commission is examining this growing body of foreign technical literature with a view of expanding its program to include translation of the most significant publications.

V. TECHNICAL REPORTS

During 1958 the Commission and its contractors issued 5,041 new unclassified technical reports and 1,382 declassified technical reports. Most of the latter were written as classified reports in previous years. Unclassified reporting on Commission-sponsored research and development, as in the past, also took two other important forms: publication of articles in professional and trade publications and presentation of papers at scientific and engineering meetings. Commission and contractor personnel published approximately 1,800 technical articles and presented an estimated 1,000 papers at professional gatherings. Papers presented by Commission and contractor scientists and engineers at the second international conference alone numbered more than 450.

All unclassified and declassified technical reports are announced in Nuclear Science Abstracts and placed on sale at the Office of Technical Services, Department of Commerce. Microcopies of the reports are sold by the Microcard Foun-

dation, Post Office Box 2145, Madison 5, Wis.; and the Readex Micro-print Corp., 115 University Place, New York 3, N.Y.

The Commission issued 1,700 classified technical reports during 1958.

Classified reports placed in the access-permit program are announced in the appropriate abstract journal (Confidential Reports for Civilian Applications or Secret Reports for Civilian Applications) and placed on sale at the Commission's Technical Information Service Extension, Oak Ridge, Tenn.

VI. ENGINEERING DRAWINGS

For several years the Commission has provided the industrial and scientific communities with engineering drawings and related information items (specifications, parts lists, bills of materials, design data, etc.) pertaining to equipment, processes, and facilities developed in the national atomic energy program. Since this service was established more than 54,000 copies of drawings and other engineering materials have been sold to the public. These have run the gamut of nuclear equipment and processes from portable radiation detectors and tiny laboratory gadgetry to complete research and power reactors and plants for processing uranium.

During 1958 the Commission added 6,000 new drawings to the engineering materials portfolio available to the public, and started cataloging some 5,000 additional items which will be announced for sale by mid-1959. The Commission took another important step in 1958; namely, that of turning over the reproduction and sale of the drawings to private enterprise. After soliciting proposals from a number of firms specializing in blueprinting and photo-reproduction work, the Commission selected the following organizations to act as reproduction and sales agents: Cooper-Trent Blueprint & Microfilm Corp., Arlington, Va.; Rapid Blueprint Co., Los Angeles, Calif.; and University Microfilms Corp., Ann Arbor, Mich. These firms offer reproductions in a wide variety of media and sizes to meet industrial and institutional needs.

The Commission's engineering materials portfolio is described in the Engineering Materials List (TID–4100, revised). New materials are announced in looseleaf supplements. Copies of the Engineering Materials List and supplements may be obtained without charge from the Technical Information Service Extension, U.S. Atomic Energy Commission, Post Office Box 62, Oak Ridge, Tenn. Copies of the drawings described in the list may be examined at any one of the following depository libraries of the Commission:

California: Menlo Park Stanford Research Institute.
District of Columbia: Washington, U.S. Atomic Energy Commission.
Idaho: Idaho Falls, Phillips Petroleum Co.
Illinois: Lemont, Argonne National Laboratory.
Massachusetts: Cambridge, Massachusetts Institute of Technology.
New York: New York, U.S. Atomic Energy Commission, New York Operations Office.
Pennsylvania: Pittsburgh, Carnegie Library of Pittsburgh.
Tennessee: Oak Ridge, U.S. Atomic Energy Commission, Technical Information Service Extension.

VII. DEPOSITORY LIBRARIES

Domestic depository libraries

During 1958 the Commission established domestic depository libraries at two new participating institutions. Shipment of literature collections to these institutions brought the total number of domestic depositories to 82. All domestic depositories are listed in appendix VII–A. New depositories are so identified.

Each collection currently contains 19,100 technical reports (15,600 in microcard form and 3,500 in full-size copy), 95 books, and 12 volumes of Nuclear Science Abstracts. New issues of Nuclear Science Abstracts and new unclassified technical reports are sent routinely to all depositories.

Foreign depository libraries

The Commission added six countries to its system of foreign depository libraries in 1958. Foreign depositories, now numbering 75, are listed in appendix VII–B. New depositories are so identified. Literature collections and services provided foreign establishments are identical to those provided domestic participants.

Classified depository libraries

Eight classified depository libraries have now been established to serve access-permit program participants. These libraries, listed in appendix VII–C, contain complete collections of classified reports released in the access-permit program and the classified abstract journals, Confidential Reports for Civilian Applications and Secret Reports for Civilian Applications.

VIII. TECHNICAL FILMS

During 1958 the Commission increased from 23 to 71 titles its holdings of professional level motion-picture films on atomic energy subjects. The films are much in demand for use at meetings of scientific and engineering societies, seminars for advanced undergraduate and graduate students, and gatherings of industrial scientists and engineers. With a view to maximizing the use of these valuable training and technical reporting resources, the Commission maintains 11 domestic film loan libraries and has made similar arrangements abroad. In addition, it has arranged for commercial sale of the films.

Forty-five of the forty-eight new films added to the Commission's holding last year were presented at the Second International Conference on the Peaceful Uses of Atomic Energy. Each was presented in four languages: English, Spanish, French, and Russian. Produced in color and ranging in length from 5 to 55 minutes, the films cover a wide variety of topics, including power reactors, research and test reactors, reactor safety, reactor fuels and fuel processing, particle accelerators, controlled thermonuclear research, and uses of isotopes and radiation in industry, agriculture, medicine, and research. All but nine of the films were produced by the Commission and its contractors.

English versions of the Geneva films have been placed in the domestic film libraries and in the Commission's London and Tokyo offices. French and Spanish versions are being reproduced and forwarded to the Commission's Brussels and Buenos Aires offices, respectively. Complete sets of the films (in all four languages) have been provided the U.S. Information Agency and the International Atomic Energy Agency. USIA is also distributing selected titles to key posts overseas. Commercial sale of the English versions has begun and arrangements are being finalized for the sale of those presented in the other three languages.

Titles and descriptions of all professional level films available from the Commission, the locations of film loan libraries, and the names of commercial suppliers are given in the booklet, "Professional Level Film List," a copy of which is enclosed as appendix VIII–A.

IX. MAJOR DECLASSIFICATION ACTIONS

The Commission took the following major declassification actions in 1958:

1. Declassified depleted uranium assaying 0.22 ± 0.02 percent U^{235} and a schedule of charges for depleted uranium.
2. Placed Project Sherwood in the unclassified fields of research.
3. Declassified all information on uranium metal production plants located at Destrahan Street, St. Louis, and Weldon Springs, Mo., except for uranium metal and intermediate compound production rates of the Destrahan Street plants prior to fiscal year 1955.
4. Declassified plutonium fuel element fabrication technology and the metallurgy of plutonium alloys containing up to 90 atomic percent plutonium.
5. Added six reactors—merchant ship, ZPR–IV, ZPR–V, ZPR–VII, Borax–V, and 3-foot exponential—to the list of reactors in unclassified fields of research.

X. REVIEW OF ACCESS PERMIT PROGRAM

The Commission took three major actions affecting the access-permit program during 1958. These actions and statistical highlights of the program are summarized below.

Effective July 1, 1958, the Commission transferred the function of issuing access permits from the Washington headquarters to the operations offices. The operations offices had been administering the permits since the inception of the program in 1955; thus, delegation of the issuance function completed the decentralization of the program. Permits are now issued and administered by

the Albuquerque, Chicago, Hanford, Idaho, New York, Oak Ridge, San Francisco, and Savannah River Operations Offices.

Direction of the access-permit program was transferred in October 1958 from the Office of Industrial Development to the Division of Reactor Development. This transfer was part of a reorganization plan under which the Division of Reactor Development was assigned responsibility for developing policy for encouraging and assisting private activities in the civilian applications of atomic energy, with the exception of isotopes and radiation programs which were assigned to a newly created Office of Isotopes Development.

On November 19, 1958, the Commission announced that after December 31, 1958, it would no longer provide free personnel security clearances to permitholders, with the exception of nonprofit educational institutions. Prior to that date the Commission provided each permitholder 25 clearance requests without charge. At present the charges are $385 for each "Q" clearance and $15 for each "L" clearance.

Statistical highlights of access-permit program calendar year 1958

Permits in effect as of Dec. 31, 1958:	
Permits for access to confidential restricted data	552
Permits for access to secret restricted data	850
Total permits	1,402
New applications:	
Applications pending on Jan. 1, 1958	30
Applications received during year	205
Permits issued	170
Applications denied	1
Applications inactivated [1]	60
Applications pending on Dec. 31, 1958	4
Renewal applications:	
Applications pending on Jan. 1, 1959	46
Renewal applications received	566
Permits renewed	478
Renewal applications inactivated [1]	102
Applications pending on Dec. 31, 1958	32

[1] When an applicant does not initially provide the Commission with sufficient information to evaluate and act on his application he is requested to provide additional information. If, after 60 days, the applicant has not replied to this request, his application is inactivated.

Appendix I–A

Bibliographies Published by the U.S. Atomic Energy Commission in 1958

1. TID–3068: Shippingport Reactor.
2. TID–3072: Thermonuclear Processes.
3. TID–3073: Reactor Safety.
4. TID–3076: Isotopes.
5. TID–3085: Nuclear Science.
6. TID–3305: Heat Transfer.
7. TID–3311: Radioactive Waste Processing and Disposal.
8. TID–3512: Isotopes.
9. TID–3513: Isotopes.
10. TID–3514: Isotopes.
11. TID–3522: Peaceful Uses of Nuclear Explosions.
12. TID–LS–32: Plutonium in Reactor Fuels.
13. TID–LS–33: Rare Earths in Reactor Control.
14. TID–LS–35: Radiation Effects on Insulation.
15. TID–LS–36: Power Reactor Control Rod Drives.

The United States Atomic Energy Commission announces

POWER REACTOR TECHNOLOGY

a quarterly review of development

prepared by
Dr. Walter H. Zinn and Associates
of the General Nuclear Engineering Corp.
under contract to the
U. S. ATOMIC ENERGY COMMISSION

This new journal in the Commission's Technical Progress Review Series summarizes and evaluates current developments in power reactor technology. Issued quarterly, it reports both on research and development results applicable to reactors generally and on progress made with specific reactor types. Each issue will vary in topical content. However, the following areas will be reviewed from time to time as developments warrant:

GENERAL RESEARCH AND DEVELOPMENT

Applications, Performance and Evaluations
Heat Transfer
Reactor Kinetics and Control
Safeguards and Containment
Shielding
Reactor Components
Fuel Handling
Materials and Radiation Effects

PROGRESS ON SPECIFIC REACTOR TYPES

Pressurized Water Reactors
Boiling Water Reactors
Liquid Metal-Cooled Reactors
Gas-Cooled Reactors
Aqueous Homogeneous Reactors
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The United States Atomic Energy Commission announces

REACTOR FUEL PROCESSING | **a quarterly review of developments**

Prepared by Dr. Stephen Lawroski and associates, Chemical Engineering Division, Argonne National Laboratory, under contract to the U. S. Atomic Energy Commission

This new journal in the Commission's Technical Progress Review series summarizes and evaluates current developments in reactor fuel processing. Issued quarterly, it reports on scientific and technological progress in this processing field resulting from AEC-sponsored programs and, insofar as possible, from industry-sponsored programs. Each issue will vary in content, with the following areas reviewed from time to time as developments warrant:

ESTIMATED PROCESSING NEEDS
- Reactor Discharge Schedules
- Fuel Compositions and Burnups
- Fuel Quantities

RESEARCH, DEVELOPMENT, ENGINEERING PROGRESS IN PROCESSING
- Fuel Disassembly and Dissolution
- Solvent Extraction
- Fluoride Volatility Processing
- Pyrometallurgical Processing
- Homogeneous Reactor Fuel Processing
- Instrumentation and Special Equipment

WASTE PROCESSING, HANDLING AND STORAGE
- Handling and Processing Wastes for Storage
- Processes for Isolating and Recovering Fission Products, Heavy Elements, etc.

PRODUCT CONVERSION STEPS
- Denitration and Conversion to Oxides, Fluorides, and Metals

PROCESSING COSTS AND PRICES
- Specifications for Processes, Reagents, and Products Related to Costs and Pricing

Reactor Fuel Processing may be purchased by subscription from the Superintendent of Documents, U. S. Government Printing Office, Washington 25, D. C. Use of the attached coupon will facilitate the handling of your order.

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The United States Atomic Energy Commission announces

REACTOR CORE MATERIALS

a quarterly review of developments in solid materials for use in reactor cores

Prepared by R. W. Dayton, E. M. Simons and associates of Battelle Memorial Institute under contract to the U. S. Atomic Energy Commission

This new journal in the Commission's Technical Progress Review series summarizes and evaluates current developments related to solid materials for reactor cores. Issued quarterly, it reports on scientific and technological progress in the following areas:

FUEL AND FERTILE MATERIALS

- Uranium; plutonium; thorium (Unalloyed and alloyed metals)
- Dispersion fuel materials
- Refractory fuel and fertile materials
- Radiation effects on fuel materials

MODERATOR MATERIALS

- Graphite
- Beryllium metal, alloys and compounds
- Solid hydrides (calcium, niobium, zirconium)

CONTROL MATERIALS

- Dispersions
- Control-rod alloys (hafnium, silver, boron, cadmium)

CLADDING AND STRUCTURAL MATERIALS

- Corrosion properties
- Radiation effects
- Selected mechanical properties

SPECIAL FABRICATION TECHNIQUES

- Melting; hot and cold working
- Cladding; welding and brazing
- Nondestructive testing

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APPENDIX III–A

TECHNICAL BOOKS PUBLISHED BY U.S. ATOMIC ENERGY COMMISSION IN 1958

"Atoms for Peace: U.S.A. 1958," Edited by J. F. Hogerton, Arthur D. Little, Inc., Cambridge, Mass.; Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.; 162 pages, profusely illustrated, 9 by 12, $4.50

A pictorial survey of the growing industrial and Government atomic energy installations in the United States. Prepared for the AEC by Arthur D. Little, Inc., for the Second Atoms-for-Peace Conference, Geneva, 1958.

Since the First International Conference on the Peaceful Uses of Atomic Energy, also held in Geneva, in 1955, some 2,500 men and women from 72 countries have visited the United States on atomic energy pursuits and have seen the growing industrial and Government atomic energy facilities of this country. This book was designed as a type of conducted tour, illustrating some of the things that were seen by those who visited these facilities.

Contents: The research and development network. Power reactor development. The production network. Research on thermonuclear power. Isotopes and radiation. Research for the future. International cooperation. Chronology.

"Boiling Water Reactors,"[1] by A. W. Kramer, editor of Atomics and formerly editor of Power Engineering; Addison-Wesley Publishing Co., Inc., Reading, Mass.; 592 pages, 292 illustrations, 6¼ by 9¼, $8.50

This comprehensive reference work on the history and technology of boiling water reactors was prepared under the auspices of the Argonne National Laboratory, with the cooperation of the many scientists and engineers there who conceived and developed this type of reactor. It presents a grief history of the boiling-water concept and of the early experiments of the Argonne Laboratory, including the development and operation of the experimental boiling water reactor. The various borax experiments are described in detail. A thorough explanation is given of the physics underlying the design of the reactor, and a lengthy description of the General Electric Co.'s Vallecitos plant is included.

The book concludes with a discussion of present and future research and development programs for boiling reactors.

Contents: General principles of boiling-water reactors. Experimental investigations on boiling-water reactors. Design of boiling-water nuclear reactor systems. The experimental boiling water reactor (EBWR). EBWR operating experience. VBWR—the Vallecitos boiling-water reactor. ALPR—the Argonne low-power reactor. The Dresden Nuclear Power Station. Other boiling-water reactors. Current and future research and development programs.

"Fluid Fuel Reactors,"[2] edited by J. A. Lane and H. G. MacPherson, Oak Ridge National Laboratory, and Frank Maslan, Brookhaven National Laboratory; Addison-Wesley Publishing Co., Inc., Reading, Mass.; 1,008 pages, 338 illustrations, 6¼ by 9¼, $11.50

A comprehensive discussion of fluid-fuel reactors which summarizes results of research carried on in the United States for almost 10 years. The book treats three basic types of fluid-fuel reactors: aqueous homogeneous, fused salt, and liquid metal fuel. A unique feature of this work is its approach to the subject from the chemical standpoint rather than from the point of view of mechanical engineering.

Contents: Part I—Aqueous homogeneous reactors. Homogeneous reactors and their development. Nuclear characteristics of one- and two-region homogeneous reactors. Properties of aqueous fuel solutions. Technology of aqueous suspensions. Integrity of metals in homogeneous reactor media. Chemical processing. Design and construction of experimental homogeneous reactors. Component development. Large-scale homogeneous reactor studies. Homogeneous reactor cost studies.

Part II—Molten-salt reactors. Chemical aspects of molten-fluoride-salt reactor fuels. Construction materials for molten-salt reactors. Nuclear aspects of molten-salt reactors. Equipment for molten-salt reactor heat-transfer systems. Aircraft reactor experiments. Conceptual design of a power reactor.

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[1] A U.S. Government presentation volume for the United Nation's 1958 Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland.

[2] Id.

Part III—Liquid-metal fuel reactors. Reactor physics for liquid-metal reactor design. Composition and properties of liquid-metal fuels. Materials of construction—metallurgy. Chemical processing. Engineering design. Liquid-metal fuel reactor design study. Additional liquid metal reactors.

"Hot Laboratory Equipment," compiled by L. G. Stang, Jr., Brookhaven National Laboratory; Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.; 429 pages, 351 illustrations, 7⅞ by 10¼, $2.50 (paperbound)

This book gives detailed descriptions and design data for facilities, equipment, and accessories used in handling moderate to large amounts of radioactive materials. It is a greatly enlarged and updated version of part II of "Chemical Processing and Equipment (TID–5276), which was published by the Atomic Energy Commission in 1955. The earlier work, known to hot laboratory specialists as "The Hot Laboratory Catalog—First Edition," contained 126 items of equipment; this revision contains 229 items.

Contents: Enclosures for radioactive operations. Viewing equipment. Manipulators. Chemical processing equipment. Equipment for measuring chemical and physical properties. Machine tools. Materials-handling equipment. Monitoring and decontamination equipment. Irradiation facilities. Special protective clothing. Shielding materials.

"Neutron Cross Sections," by D. J. Hughes and R. B. Schwartz, Brookhaven National Laboratory; Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.; 373 pages, 292 illustrations, 10½ by 15⅝, $4.50 (paperbound)

This compilation is a second edition of BNL 325 which is designed to meet the needs of reactor physicists for cross-section curve data emphasizing the energy range appropriate for pile neutrons and cross sections at thermal energy.

Contents: Thermal cross sections. Resonance parameters. Cross-section curves.

"Nuclear Reactor Experiments," by the staff of Argonne National Laboratory, edited by J. B. Hoag; D. Van Nostrand Co., Inc., Princeton, N.J.; 480 pages, 234 illustrations, 6¼ by 9¼, $6.75

A laboratory manual detailing 49 experiments involving the theory and practice of fission reactor measurements.

Contents: Some basic information. Nuclear radiation detection. Moderator assemblies. Subcritical assemblies. Cross sections. Experiments using an operating reactor. Some characteristics of operating reactors. Heat removal from a reactor. Fuel preparation for a heterogeneous reactor. Corrosion and radiation effects. A metallurgy "hot" laboratory. Separations processes. Appendixes. Index.

"Nuclear Reactor Metallurgy," by W. D. Wilkinson and W. F. Murphy, International School of Nuclear Science and Engineering, and W. J. McGonnagle, Metallurgy Division, Argonne National Laboratory; D. Van Nostrand Co., Inc., Princeton, N.J.; 382 pages, 179 illustrations, 6¼ by 9¼, $5.60

A book of course material in applied reactor metallurgy developed at the International School of Nuclear Science and Engineering of Argonne National Laboratory.

Contents: Uranium ores and ore treatments. Production of uranium metal. Structure and properties of uranium. Mechanical properties of uranium. Uranium alloys. Metallurgy of uranium. Thermal properties and heat treating of uranium. The fabrication of uranium. Powder metallurgy of uranium. Corrosion of uranium and other metals. Surface protection of uranium. The fabrication of fuel elements. Radiation damage in uranium. Metallurgy of plutonium. Metallurgy of thorium. Metallurgy of beryllium. Metallurgy of zirconium. Properties of liquid metals of interest in nuclear reactor. Ceramics in reactor technology. Metallic materials with large cross sections for thermal neutrons. Effects of neutron radiation of nonfissionable metals and alloys. Nondestructive testing of nuclear reactor components. Index.

"Physical Metallurgy of Uranium,"[3] by A. N. Holden, Vallecitos Atomic Laboratory, General Electric Co.; Addison-Wesley Publishing Co., Inc., Reading, Mass.; 272 pages, 190 illustrations, 6¼ by 9¼, $5.75

This book provides a comprehensive and unified treatment of the physical metallurgy of uranium, in which the author summarizes, correlates, and critical-

[3] Id.

ly evaluates the wealth of information that has become available in the field during the past several years. Although important experimental techniques and results are thoroughly described, emphasis has been placed upon interpretation in terms of fundamental properties and mechanisms.

Contents: History, occurrence, and preparation of metal. Radioactivity and nuclear reactions, crystallography of uranium. Physical and chemical properties of uranium. Mechanical properties of uranium. Deformation of uranium. Recovery, recrystallization, and grain growth. Transformations in uranium and uranium alloys. Growth of uranium single crystals. Diffusion in uranium systems. Radiation damage to uranium. Thermal-cycling growth of uranium. Design of metallic fuel elements. The metallography of uranium. Appendix: Uranium phase diagrams for binary systems.

"Power Reactors," compiled by the Division of Reactor Development, U.S. Atomic Energy Commission; Superintendent of Documents, U.S. Government Printing Office, Washington, D.C.; 92 pages, 75 illustrations, 7⅞ by 10⅜, 65 cents

A compact summary of technical information, prepared by the Atomic Energy Commission, on 10 full-scale nuclear power plants built, under construction or being undertaken in the United States. The text is profusely illustrated and reinforced with lengthy tabulation of data.

Contents: Pressurized-water reactors: Consolidated Edison thorium reactor, Yankee atomic electric powerplant, Army package power reactor. Boiling-water reactors: Vallecitos boiling-water reactor, Dresden Nuclear Power Station, Northern States nuclear powerplant. Sodium graphite reactor: Hallan nuclear power facility. Organic-moderated reactor: Organic-moderated reactor powerplant. Fast-breeder reactor: Enrico Fermi atomic powerplant. Sodium heavy-water reactor: Chugach nuclear powerplant.

"Project Sherwood—The U.S. Program in Controlled Fusion," [4] by Amasa Bishop, AEC's European scientific representative, Paris, France; Addison-Wesley Publishing Co., Inc., Reading, Mass.; 228 pages, 58 illustrations, 6¼ by 9¼, $5.75

A detailed account of the extensive research and development undertaken by the U.S. Atomic Energy Commission for harnessing the energy of thermonuclear reactions. The author, formerly Chief of the Commission's Controlled Thermonuclear Branch, presents a factual and readable account of Project Sherwood—based on his close contact with the program since its beginning.

This first unclassified report, written to be intelligible to the interested general reader as well as to scientists and engineers, and graphically illustrated with over 30 three-color drawings, presents a compact account of the controlled thermonuclear effort in the United States—its origin, its development, its problems, and the outlook for its eventual success. The book describes the basic principles involved in a fusion reaction, and the various methods now being studied to control thermonuclear energy, with the hope of eventually producing net power.

The volume is supplemented by a glossary of terms and appendixes designed to supply the layman with a source of basic information necessary for an understanding of the principles involved.

Contents: Basic principles of controlled fusion. The problem of confinement. The pinch program (pt. I). The stellarator program (pt. I). The magnetic mirror program (pt. I). Development of other projects (pt. I). The coordination and administration of the Sherwood program (pt. I). Plasma diagnostics. The question of stability. The pinch program (pt. II). The stellarator program (pt. II). The magnetic mirror program (pt. II). The molecular ion ignition program. The cusped-geometry program. Shock-wave experiments. The Astron program. Development of other projects (pt. II). Coordination and administration of the Sherwood program (pt. II). Summary and outlook. Appendixes: Several fundamental topics of physics. Low-temperature fusion. Thermonuclear reactions in the sun and other stars. Unpromising approaches. Glossary of terms. Glossary of symbols. Participation in Sherwood conferences. Bibliography of selected readings. Persons associated with the Sherwood project. Charts giving data on representative models of the pinch, stellarator, and magnetic mirror programs.

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[4] Id.

"Radiation Biology and Medicine: Selected Reviews in the Life Sciences,"[5] edited by W. D. Claus, Division of Biology and Medicine, U.S. Atomic Energy Commission; Addison-Wesley Publishing Co., Inc., Reading, Mass.; 968 pages, 198 illustrations, 6¼ by 9¼, $11.50

In this book devoted to the uses and effects of nuclear radiation in the life sciences, more than 50 authors review advances in thought and research in the United States. The 33 carefully selected articles constitute a valuable collection of data for biologists, physicians, and others. The book is well illustrated, and each chapter contains an extensive bibliography.

A brief discussion of training programs in radiation biology and related sciences, and a list of contracts and grants made by Government and private agencies to support research involving radiation in the biological sciences, appear as appendixes.

Contents: Part 1: Introduction. Part 2: Basic mechanisms of biological reaction to radiation. Part 3: Mutational effects of radiation. Part 4: Mathematical biology. Part 5: Mammalian response to radiation. Part 6: Radiation safety. Part 7: Medical uses of atomic radiation. Part 8. Agricultural uses of radiation. Part 9: Tracer applications. Part 10: Instrumentation and dosimetry. Appendix A: Training in radiation biology and related sciences. Appendix B: Research contracts and grants.

"The Shippingport Pressurized Water Reactor,"[5] by personnel of the Naval Reactors Branch, Division of Reactor Development, U.S. Atomic Energy Commission; Westinghouse Electric Corp., Bettis Plant; and Duquesne Light Co.; Addison-Wesley Publishing Co., Inc., Reading, Mass.; 600 pages, 163 illustrations, 6¼ by 9¼, $9.50

An account of the research and development for and construction of the first large-scale central station nuclear powerplant to be built and operated in the United States. This book was written by the scientists and engineers who designed, developed, and constructed the plant, readied it for operation, and tested it. This is the basic sourcebook for this plant and its technology. For those who want more detailed information, selected references are given at the end of each chapter.

Contents: Design philosophy. Reactor coolant system. Physics. Reactor. Fuel element development. Core manufacturing. Chemistry. Reactor plant auxiliary systems. Control and instrumentation systems. Radioactive waste disposal system. Hazards evaluation. Electrical and mechanical components. Shielding. Turbine-generator plant. Site description and development. Architectural design of the nuclear plant. Construction. Test program. Procurement. Preparation for the operation of Shippingport Atomic Power Station.

"Sodium graphite reactors,"[6] By Chauncey Starr and R. W. Dickinson, Atomics International, a division of North American Aviation; Addison-Wesley Publishing Co., Inc., Reading, Mass.; 304 pages, 99 illustrations, 6¼ by 9¼, $6.50

This book offers a unified and coherent presentation of sodium graphite reactor technology. In addition, by grouping related material into logical units, it provides a ready reference source for those interested in particular aspects of the subject.

While emphasis has been placed on the design and development of the sodium reactor experiment (SRE), the authors have, whenever possible, included information applicable to sodium graphite systems and, in many cases, to reactor design in general. The Hallam nuclear power facility, a full-scale sodium graphite plant on which construction has started, is described.

Contents: Sodium graphite reactors and their importance to the nuclear industry. Sodium reactor experiment. Nuclear and design characteristics. Materials requirements. Fuel element development. SRE components and systems. Installation and operation of SRE. Large-scale sodium graphite concepts.

"Solid Fuel Reactors,"[7] by J. R. Dietrich and W. H. Zinn, General Nuclear Engineering Corp.; Addison-Wesley Publishing Co., Inc., Reading, Mass.; 864 pages, 385 illustrations, 6¼ by 9¼, $10.75.

This volume reviews the basic concepts, present status of development in the United States, and technical and economic outlooks in this country for five pro-

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[5] Id.
[6] Id.
[7] Id.

jected solid-fuel nuclear power reactor types: fast-neutron power breeders, heavy-water reactors, gas-cooled reactors, organic moderated and cooled reactors; and a thermal reactor for recycling plutonium.

The information presented ranges from well-established experimental, theoretical, and developmental results to analyses intended chiefly to provide direction for future work.

Contents: The fast-neutron power reactor. The experimental breeder reactor. The Enrico Fermi atomic powerplant. Heavy-water power reactors. Gas-cooled reactors. Organic cooled and moderated reactors. Plutonium recycling in thermal reactors.

"Sourcebook on Atomic Energy," by Samuel Glasstone, consultant to the U.S. Atomic Energy Commission; D. Van Nostrand Co., Inc., Princeton, N.J.; 641 pages, profusely illustrated, 6¼ by 9¼, $4.40.

The second edition of the book which provides a source of basic atomic energy information for readers with varied interests.

Contents: Foundations of the atomic theory. Fundamental particles. Energy and radiation. The structure of the atom. Natural radioactivity. Measurement of nuclear radiations. Properties of nuclear radiations. Isotopes. The acceleration of charged particles. Nuclear transmutations and artificial radioactivity. The neutron. Nuclear forces and nuclear structure. Nuclear fission. The utilization of nuclear energy. Nuclear reactors. The new elements. The uses of isotopes and radiations. Cosmic rays and strange particles. Radiation protection and health physics.

"Thorium Production Technology,"[8] by F. L. Cuthbert, National Lead Co. of Ohio; Addison-Wesley Publishing Co., Inc., Reading, Mass.; 320 pages, 84 illustrations, 6¼ by 9¼, $6.50

The sourcebook on thorium production technology contains practically all the information currently available on the subject. While some of the material presented here has been accessible previously in various forms, this volume represents an extensive compilation of information on the production of thorium metal.

Contents: Thorium: history, sources, and uses. Properties of thorium. Thorium-bearing ores: their deposits and methods of concentration. Extraction of thorium from ores. Purification of thorium concentrates. Preparation of thorium metal by reduction. Melting and cast of thorium. Fabrication of thorium. Health and safety aspects of thorium production. Testing procedures.

"Uranium Ore Processing,"[9] edited by J. W. Clegg and D. D. Foley, Battelle Memorial Institute; Addison-Wesley Publishing Co., Inc., Reading, Mass.; 448 pages, 118 illustrations, 6¼ by 9¼, $7.50.

Here, for the first time in book form, is a condensed but essentially complete description of practices used in winning uranium from its ores. While the emphasis is on a well-rounded presentation of current practices in the United States, techniques in other countries are also described.

Because of its comprehensive and authoritative nature, the volume should be a valuable reference for all workers in the field. Various processes are described in full, and there are many helpful comments and observations. Each chapter is accompanied by an extensive reference list.

Contents: Uranium occurrence and sources. Uranium exploration and mining. Sampling and analysis. Mineralogy of uranium as it relates to hydrometallurgical processing. Preliminary ore treatment. Acid leaching of uranium ores. Carbonate leaching of uranium ores. Liquid-solids separations. Uranium recovery by ion exchange. Uranium recovery by solvent extraction. Examples of uranium milling operations. Uranium recovery from phosphate rock monazite, lignite, and shale. Health and safety problems associated with uranium mining and milling. Appendix: Main uranium districts of the United States.

"U.S. Research Reactor Operation and Use,"[10] edited by J. W. Chastain, Jr., Battelle Memorial Institute; Addison-Wesley Publishing Co., Inc., Reading, Mass.; 384 pages, 181 illustrations, 6¼ by 9¼, $7.50

This book sets forth information not only about technical aspects, characteristics, and operating problems, but also on administrative, legal, and cost prob-

[8] Id.
[9] Id.
[10] Id.

lems. Written primarily for scientists, engineers, and administrators considering owning or using a reactor, this volume also may serve as a text or reference for introductory courses in reactor engineering.

Contents: The research reactor. Research reactor physics. Light-water moderated heterogeneous reactors. Heavy-water reactors. Homogeneous reactors. Graphite reactors. Reactors for transient studies and special reactors. Research reactor supporting facilities. Safety considerations. Experimental research with reactors. Preroutine reactor operations. Operation and maintenance of research reactors. Cost of reactor facilities. Regulations and insurance.

Appendix III–B

Technical Books in Press or in Preparation as of February 10, 1959

"Analysis of Essential Reactor Materials," edited by C. J. Rodden, Director of AEC's New Brunswick (N.J.) Laboratory; contributions from authorities (being written; to be ready for publisher in spring of 1960)

This book will extend the coverage of and bring up to date Mr. Rodden's Analytical Chemistry of the Manhattan project, which was published in 1950 as a volume of the national nuclear energy series. The book will be a compilation of the analytical methods presently used for the analysis of many materials used in atomic energy. It will be divided into two parts: one describing methods for the determination of individual elements and one dealing with general instrumental methods. The book is being written for analytical chemists.

Contents: Uranium. Thorium. Plutonium. Beryllium. Zirconium and hafnium. Deuterium and tritium. Rare earths. Graphite. Expended reactor fuel analysis. Trade element analysis. Electrometric methods. Mass spectrometry. Radiochemical methods.

"Commercial Nuclear Ship Propulsion," by A. W. Kramer, editor of Atomics and formerly editor of Power Engineering (writing starting; to be ready for publisher during winter 1959–60).

This will, in effect, be a sourcebook on commercial nuclear ship propulsion. Commercial shipping people, port authorities, regulation officials, construction and design engineers, and interested laymen and writers will find it a valuable source of information. Selected references will direct them to additional material.

A substantial portion of the book will be devoted to the U.S. NS *Savannah*, the first commercial nuclear ship, to be launched during 1959. It will also include operating and environmental considerations, servicing, training the crew, insurance, economics, and suitability of different types of reactors for commercial ships.

"Controlled Thermonuclear Reactions," by Samuel Glasstone, consultant to the Atomic Energy Commission (writing underway; to be ready for publisher during winter of 1959–60)

The principles of controlled thermonuclear reactions will be presented by Samuel Glasstone in the lucid style that has characterized his other books on atomic energy. Thermonuclear processes are introduced so as to be understandable by physicists and engineers who have no background in this field. At the same time, fundamentals and techniques of thermonuclear research are explained completely enough to supply the foundation needed by one setting out in a research program.

The book describes the conditions that are required for controlled thermonuclear reactions and the possible routes by which these conditions may be achieved. Plasma theory is discussed employing mathematics of adequate level. Equipment such as pinch and mirror devices are described together with stellarator and other methods of creating and heating plasma. Experimental techniques employed in controlled thermonuclear research also receive attention.

"Critical and Subcritical Assemblies and Their Use in Reactor Design," by Dixon Callihan, Oak Ridge National Laboratory; with contributions from W. C. Redman, Argonne National Laboratory; Herbert Kouts, Brookhaven National Laboratory; and Edward C. Campbell, Oak Ridge National Laboratory (writing started; to be ready for publisher in fall of 1960)

Here is a volume that will meet not only the needs of the student or young engineer faced with the problem of learning about the field of critical and subcritical experiments, but also many others—it will be of importance to industrial concerns operating or about to construct critical facilities, to universities engaged in low-power and exponential experiments, to reactor designers who want to know more about the tools available to them, and to men already in the field who desire to have the latest on the subject in a readily available form.

Authorities from three national laboratories are writing the book. Dr. Callihan from Oak Ridge describes the purpose and needs of critical experiments, discusses the design of a critical assembly laboratory and the experimental equipment required. Operational procedures based on his extensive experience are presented.

Dr. Kouts of Brookhaven describes exponential experiments—both homogeneous and heterogeneous assemblies. Flux measurements, buckling, and the sources commonly used are covered. A comparison of exponential and critical experiments is made.

Dr. Campbell of ORNL describes the use of pulsed neutrons from acceleration for criticality work and discusses the potentials of this method. Dr. Redman of Argonne describes reactor design by zero power experimentation. A few of the items covered by Dr. Redman are the measurement of nuclear parameters, the information that can be obtained from flux plots and how to use it, determination of reactivity effects, and the calibration of control systems.

"Cryogenic Engineering," by R. B. Scott, Chief, Cryogenic Engineering Laboratory, National Bureau of Standards, Boulder, Colo.; D. Van Nostrand Co., Inc., Princeton, N.J.; about 488 pages, 207 illustrations, 6¼ by 9¼, $5.60 (publication scheduled for March of 1959)

This book, prepared by the National Bureau of Standards for the Atomic Energy Commission, is intended primarily for students, engineers, and scientists who are unfamiliar with low-temperature techniques. It outlines the practical aspects of cryogenic processes and equipment, at the same time providing a careful discussion of the underlying theory.

The entire range of cryogenic engineering is covered—the development and improvement of low-temperature processes and equipment; the determination of the physical properties of materials used to produce, maintain, and utilize low temperatures; and the practical application of low-temperature techniques and processes. The author has selected the most important and useful developments, concentrating on those features which seem likely to have further applications.

Contents: Advances in cryogenic technology. Industrial applications of cryogenics. Cryogenics in rocketry. Engineering research and development at low temperatures. Liquefaction of gases. Separation of gases. Cooling by adiabatic demagnetization. Low-temperature thermometry. Insulation. Storing and transporting liquefied gases. Transfer of liquefied gases. Properties of cryogenic fluids. Low-temperature properties of structural materials. Appendix. Index.

"Disposal of High-Level Wastes," by Eli I. Goodman and Herman L. Sturga, Nuclear Science and Engineering Corp. (nearing completion; to be ready for publisher in summer of 1959)

This book is an organized compilation of information on high-level, liquid, radioactive waste disposal obtained from a wide variety of project reports, compilations of individual papers, progress reports, operations manuals, plant trips, and private communications.

Contents: Fundamentals. Nature of the wastes. Radiological safety. Economics. Storage tanks and waste volumes. Treatment. Final disposal.

"Effects of Radiation on Organic Materials," by James Carroll and Robert Bolt, California Research Corp.; with contributions from others (detailed outline completed; work started on individual chapters; to be ready for the publisher during fall of 1959)

This book, covering the effects of radiation on organics, will be useful to both the radiation effects experimenter and the designer. Theory will not be detailed but will be adequate so that one can reasonably predict the nature and amount of radiation effects on a certain type of material. The behavior of organic materials under irradiation varies widely. (For example, ethylene glycol, which was formerly thought to be satisfactory as a heat transfer medium

in a radiation field, is no longer used because of its decomposition under irradiation.)

Numerous tables and charts will be given showing experimental results. This collection of information is vital to the engineer who must specify the gaskets, coolants, and lubricants to be used in strong radiation fields. The information is valuable to the experimenter because it shows what has been learned so far and helps him to orient his research. There is an introductory chapter, a chapter on the interaction of ionizing radiation with matter, and one on the chemical effects of ionizing radiation. Some of the items covered in separate chapters are effects of radiation on plastics, elastomers, fuels, and lubricants.

"Engineering for Nuclear Reactor Fuel Processing," by F. L. Culler, J. T. Long, W. L. Carter, and A. M. Rom, Oak Ridge National Laboratory (writing underway; to be ready for published during fall of 1959)

The fundamentals of chemical reprocessing of reactor fuel will be correlated and presented primarily for engineers employing radioactive chemical processes. The book is more than a description of the processes that have been developed for use in the atomic energy program; it combines in useful form the Commission's production experience with a large stock of research and development information. Data are reorganized and presented in fundamental units, making it significant to the general chemical engineer as well as to the radiochemical engineer.

The volume should be useful to designers and students alike in the areas of solvent extraction, ion exchange, distillation, and other mass diffusion operations, particularly where remote operation and control are of interest. In addition to the mass-diffusion operations, the book will treat special techniques required in radiochemical processing, including those concerned with fluid flow, heat transfer, and instrumentation. It will contain chapters on plant design, plant operation, and fuel-processing economics.

"Fast Breeder Reactor Handbook," by A. Amarosi and others of Atomic Power Development Associates (to be ready for publisher in spring of 1961)

This handbook is to be a compendium of fast-breeder technology in two volumes, one on plant design and the other on reactor theory and core design.

"Irradiation Testing and Hot Lab Techniques," edited by D. M. Wroughton, Bettis Plant, Westinghouse Electric Corp.; T. J. Glasson, Knolls Atomic Power Laboratory, General Electric Co.; and R. R. Roof, Naval Reactor Branch, Division of Reactor Development, Atomic Energy Commission; under sponsorship of AEC's Naval Reactors Branch (to be ready for publisher in spring of 1960)

This book will describe the facilities and techniques used in carrying out irradiation tests on fuels and other reactor materials.

"Management of Nuclear Materials," by R. F. Lumb, Quantum, Inc., with contributions by others (manuscript nearing completion; to be ready for publisher in summer of 1959)

This books presents techniques used in the management and control of special nuclear materials. These techniques include: (1) Obtaining data by sampling, weighing, and analyzing analytically; (2) taking, verifying, and maintaining inventory; (3) recording data on individual forms and periodic reports; and (4) controlling data flow and data utilization. A brief description of the processes are given to serve as a background for these techniques These processes include the entire spectrum of AEC operations from ore buying through scrap recovery from rector operations.

The audience includes companies presently processing nuclear materials wishing to evaluate their management system, together with companies interested in the AEC field wanting to determine what is involved in accounting for nuclear materials.

This book begins with a discussion of the philosophy of nuclear materials management, continues with a general description of records and statistical techniques, and then discusses detailed nuclear management considerations of each process. Present techniques are discussed, but it is not intended that the reader use this discussion as a cookbook to utilize the techniques directly—but rather as a description giving the reader a feeling for what is involved in nuclear materials management.

Contents: Basic management considerations. Ore processing. Feed materials. Reactor fuel fabrication. Reactor operation. Recovery. Research and development facilities.

"Metallurgy and Fabrication of Fuel Elements," by Dr. A. R. Kaufmann and others of Nuclear Metals, Inc. (writing nearing completion; to be ready for publisher during the summer of 1959)

Metallurgists and fabrication specialists interested in the production of nuclear reactor fuel elements will find this volume indispensable. Reactor engineers will obtain from it much useful information for conceptual design purposes.

The book describes all aspects of fuel elements—the materials, the production, the assembling, and the inspection. In a series of introductory chapters, the metallurgist is acquainted with the nature of nuclear reactors, the conditions which fuel elements will encounter in reactors, and the important physics and engineering design factors.

Following the introduction, the metallurgy of uranium, thorium, plutonium, and their alloys, plus ceramics and cermets, are described in some detail. The choice of cladding material is then discussed.

In the light of this background, the manufacturing procedures for producing fuel elements from the various components and for assembling them into clusters are described at length. Useful inspection methods are related to the manufacturing steps in a separate chapter.

In the development of new fuel elements, all future costs must be considered. Therefore, a brief discussion on fuel element economics and reprocessing problems is included. A short chapter on fluid fuels provides perspective on homogeneous reactors.

A glossary of terms useful for the nuclear man who wishes to understand metallurgy terminology or for the metallurgist unfamiliar with the jargon of the nuclear engineer appears at the end of the book. For completeness, phase diagrams of uranium, thorium, and plutonium and their alloys are included in an appendix.

"The Metallurgy of Hafnium," edited by D. E. Thomas, Bettis Plant, Westinghouse Electric Corp., and E. T. Hayes, Bureau of Mines, U.S. Department of the Interior, undersponsorship of AEC's Naval Reactors Branch (to be ready for publisher in spring of 1959)

This is a reference work dealing with the science and technology of the extraction, fabrication, properties, and uses of the metal hafnium. Individual chapters, written by recognized authorities in their respective fields, present information generally unavailable previously.

The book—illustrated by 85 line drawings and photographs—follows the natural sequence of functions involved in processing the ore through to a finished product.

Contents: Applications. Extraction from ores. Reduction processes. Refining. Melting, fabrication, and shaping. Constitution of alloys. Physical metallurgy and properties. Analytical chemistry. Properties of compounds. Appendix: Industrial hygiene and safety.

"Neutron Absorber Materials for Reactor Control," by W. K. Anderson, Knolls Atomic Power Laboratory, General Electric Co., and J. S. Theilacker, Bettis Plant, Westinghouse Electric Corp., under sponsorship of AEC's Naval Reactor Branch (to be ready for publisher in summer of 1959)

This well-illustrated book reviews all available information on materials that are either currently being used or have potential use in the control of nuclear reactors.

Contents: Basic concepts. Nuclear theory and calculations for control rod design and for burnable poison design. Relationships between control materials and reactor systems. Mechanical requirements for control systems. Hafnium. Boron materials. Silver and its alloys. Rare earth materials. Selection of control materials for particular reactor applications. Fuel systems containing dispersed burnable poisons. Selection of burnable poison materials for particular reactor applications. Appendixes. Index.

"Nuclear Radiations in Science and Industry," by L. E. Brownell, University of Michigan (nearing completion; to be ready for publisher in fall of 1959)

This is an orientation, or introductory, book to the broad field of the use of radiation in science and industry. The author writes for the technical reader

of any discipline and in such a way that the text will be helpful to the diligent, inquiring layman. More information than that in the necessarily condensed chapters can be found in the numerous selected references at the end of each chapter.

Contents: Nuclear radiation and controlled fission. Using nuclear radiations from reactors. Using nuclear radiations in industry. Promoting chemical reactions by ionizing radiations. Tracers and autoradiography. Radioisotopes in medical diagnosis and investigation. Nuclear radiations in medical treatment. Effects of ionizing radiation on biological materials and simple organisms. Effects of ionizing radiation on plants, foods, and pharmaceuticals. Possible commercial applications of biological effects of gamma radiation. Health physics and instrumentation.

"Nuclear Reactor Design Manual," edited by N. J. Palladino and B. F. Langer, Bettis Plant, Westinghouse Electric Corp., and I. H. Mandil, Naval Reactors Branch, Division of Reactor Development, AEC; under sponsorship of AEC's Naval Reactors Branch (to be ready for publisher in fall of 1959)

This manual will detail the techniques developed in designing pressurized water reactors for various naval uses and the Shippingport pressurized-water reactor.

"Properties of Uranium Dioxide," edited by J. Belle, Bettis Plant, Westinghouse Electric Corp.; contributions by other authorities; under sponsorship of AEC's Naval Reactors Branch (to be ready for publisher in summer of 1959)

This book presents information acquired from the development of uranium dioxide as a reactor fuel and from use of dioxide fuel elements; it includes experience of Bettis Plant and suppliers in obtaining, fabricating, and testing the material.

Contents: Uranium dioxide and its application to nuclear reactors. Preparation. Characterization. Fabrication. Physical properties. Phase relationships in UO_2–U_3O_8 system. Solid state reactions. Oxidation and corrosion. Irradiation behavior. Metallography.

"Radiation Damage to Reactor Fuels," J. P. Howe, Atomics International, and others (being written; to be ready for publisher in summer of 1960)

The task of correlating the vast accumulation of data on radiation effects on fuel materials and presenting this information in an organized manner has been undertaken. Trends toward principles will be indicated whenever possible. The behavior of fuels in use in reactors will be described and classified. Primary effects from fission will be discussed in detail, for example: growth; swelling; phase transformations; mechanical, thermal, and electrical property changes; ionization effects in nonmetals; and recovery from damage. The radiation behavior of different classes of fuels—metallic fuels in massive form, dispersed fuels in inert metal and plastic base, and refractory compound base fuels—will be described.

"Radiation Safety for Industrial Management," by National Industrial Conference Board staff (being written; to be ready for publisher in spring of 1960)

This book is designed to inform executives, managers, and administrators about the hazards of atomic energy and safety procedures so that benefits of atomic energy application can be realized more readily throughout industry. This book will present information from many organizations that use radiation advantageously and safely.

The coverage includes the nature of radiation and its biological effects, employee and public relations, codes, regulations, insurance, and workingman's compensation. There is a chapter each on several different kinds of facilities where radiation is present; namely, power reactors, research reactors, irradiation facilities, laboratories using radioactive materials, chemical plants processing spent reactor fuel, and uranium mining and processing installations.

"Reactor Handbook": Volume I—"Physics and Shielding," H. Soodak and E. P. Blizard, editors; Volume II—"Engineering," S. McLain, editor; Volume III—"Materials," C. R. Tipton, Jr., editor; Volume IV—"Fuel Reprocessing," R. B. Richards, editor.

To be published in four volumes, the "Reactor Handbook" will provide authoritative accounts of nuclear theory, data, hardware, and processes developed in atomic energy programs. Representing the efforts of several hundred authors

and contributors, each a well-known scientist or engineer in his field, the handbook is intended as a desk reference for technical people engaged in research, development, and design. More than 3 years of effort have gone into the preparation of the four volumes. The preparation process of gathering, evaluating, digesting, and organizing the vast quantity of nuclear information and data included in the four volumes was under the guidance of an eminent editorial review board. Members of this review board are H. Brooks, P. F. Gast, J. P. Howe, S. Lawroski, M. C. Leverett, and W. H. Zinn, chairman.

Contents: Volume I—"Part A—Physics," edited by H. Soodak, Nuclear Development Corp. of America; Part B—Radiation Shielding," edited by E. P. Blizard, Oak Ridge National Laboratory (to be ready for publisher by fall of 1959).

Contents: "Part A—Physics": Nuclear data. Experimental methods. Theory of neutron transport. Experimental reactor statistics. Theoretical reactor statistics. Reactor dynamics. "Part B—Radiation Shielding": Neutron and gamma ray sources. Units and exposure levels. Gamma ray attenuation. Neutron attenuation. Geometry, ducts and voids in shields. Heat generation in shields. Shield optimization. Scattering.

Volume II—"Engineering," edited by S. McLain (to be ready for publisher in spring of 1959).

Contents: Fluid flow and heat transfer. Heat generation. Stress analysis. Fuel-element design. Coolants. Control systems. Shielding. Reactor operation. Hazards. Plant layout. Plant management. Hood and cave design. Development procedures. H_2O and D_2O cooled systems. Liquid-metal cooled systems. Gas-cooled systems. Aqueous fuel systems. Liquid-metal fuel systems. Fused-salt systems. Organic-moderated systems. Reactor designs.

Volume III—"Materials," edited by C. R. Tipton, Jr., Battelle Memorial Institute (to be ready for publisher by spring of 1959).

Contents: Handling fuel and fertile materials: Radiation damage. D_2O and H_2O separation. Zirconium-hafnium separation. Constitutional diagrams. Properties of: Fuel and fertile materials; cladding, structural, control, moderator, and shielding materials.

Volume IV—"Fuel Reprocessing," edited by R. B. Richards, Hanford Atomic Products Division, General Electric Co. (to be ready for published in summer of 1959).

Contents: Fuel cycles. Aqueous separations processes. Nonaqueous separations processes. Reconversion of fuel. Radioactive waste disposal. Engineering of equipment and plants. Economics.

"Reactor Heat Transfer and Fluid Flow Handbook," edited by J. Zerbe, Bettis Plant, Westinghuse Electric Corp., under sponsorship of AEC's Naval Reactors Branch (to be ready for publisher in fall of 1959)

This handbook will present heat transfer and fluid flow information used in designing pressurized-water reactors for naval uses and the Shippingport pressured-water reactor.

"Reactor Plant Piping Handbook," edited by M. Shaw, Naval Reactors Branch, Division of Reactor Development, AEC, under sponsorship of AEC's Naval Reactors Branch (to be ready for publisher in summer of 1959)

This book will detail the technology related to the design, fabrication, and maintenance of primary plant piping systems for pressurized-water nuclear powerplants.

"Techniques of Conducting Irradiation Effects Experiments," by H. W. Etherington and others of ACF Industries (in preparation; to be ready for publisher in fall of 1959)

This book is designed to give engineers new to the field of irradiation experiments an understanding of the problems inherent in this kind of testing—from a simple capsule type of experiment to a complicated engineering loop that has its own systems for heat transfer, pressurizing, and purifying. In addition to general discussion of different classes of experiments, detailed coverage of representative experiments is given.

Contents: Planning the irradiation test. Nuclear considerations. Design analysis. Instrumentation. Safety aspects of irradiation testing. Preirradiation testing and installation of the experiment. Postirradiation transfer and handling. Experimental capsules. ANL–MTR high-pressure water loop experiment. Autoclave experiments. Bulk-irradiation experiments.

"Thermal Stress in Reactor Design," by Franklin Institute staff (writing in progress; to be ready for publisher in spring of 1960)

This book is being written for the nuclear engineer and graduate student planning to enter the nuclear field. It brings together in one volume the general thermal stress theory and mathematics needed by nuclear engineers and discusses applications in the nuclear field. Chapters in the general section of the book include heat transfer in thermal stress analysis, thermal stress under elastic and plastic conditions, and design consideration. The applications part of the book includes discussion of thermal stress in fuel elements, reactor vessel, heat exchangers, and other reactor components.

"Treatment and Disposal of Low-Level Radioactive Wastes," by Conrad P. Straub, Robert A. Taft Sanitary Engineering Center, (writing in progress; to be ready for publisher in fall of 1959)

This book presents all unclassified information useful to a firm entering the atomic energy industry and beinning to encounter the problems of radioactive waste disposal. It will be understandable to the engineer or scientist in industry who does not have a thorough knowledge of nuclear radiation and its hazards. At the same time, the book will be a convenient source of reference for the engineer and scientist already in the field.

Contents: Section I. Liquid Wastes—Sources, quantity, and composition; collection, sampling, and measurement; direct discharge to environment; removal of radioactivity by water treatment; removal of activity by sewage treatment; treatment at site (chemical precipitation, adsorption, ion exchange, electrodialysis, solvent extractions, evaporation, and storage); public health implications. Section II. Solid Wastes—Sources, quantities, and composition; collection, sampling, and measurement; baling or incineration; land burial; sea disposal of packaged material; public health implications; decontamination; liquid waste collection, treatment, and disposal; and solids waste collection, treatment, and disposal.

"Uranium Production Technology," edited by C. D. Harrington and A. E. Ruehle, Mallinckrodt Chemical Works, with contributions from others (being published by D. Van Nostrand Co.; galley proofs will be ready in early March; approximately 600 pages and 300 illustrations)

This book presents the entire field of the technology in the United States of uranium metal production from uranium concentrates or high-grade uranium ore. It includes a description of the diethyl ether and tributyl phosphate solvent extraction, deoxidation, hydrofluorination, reduction, and casting processes. Rolling, forging, extrusion, and machining fabrication techniques are also discussed, along with the chemistry and physical metallurgy of uranium. Chapters on uranium alloys, producing uranium hexafluoride, producing enriched uranium, new technology, and health hazard control complete the book. Limited amounts of history, pertinent production details, and development work are included. This comprehensive book, the first in its field, includes work done at many AEC installations throughout this country. It is written for the student of metallurgy both in an academic institution and in industry.

Contents: Chemistry of uranium processing. Diethyl ether solvent extraction process. Tributyl phosphate solvent extraction process. Producing uranium trioxide. Producing uranium dioxide. Producing uranium tetrafluoride. Producing uranium metal by reduction and casting. Producing dingot uranium metal. Process physical metallurgy of uranium. Fabricating uranium metal-press forging in alpha range. Fabricating uranium metal primary extrusion. Fabricating uranium metal-rolling and slug machining. Producing and fabricating high uranium alloys. Producing uranium hexafluoride. Producing enriched compounds and metals. Recent work in uranium technology. Health hazard control.

"The Physics of Intermediate Spectrum Reactors," edited by J. R. Stehn, Knolls Atomic Power Laboratory; Superintendent of Documents, U.S. Government Printing Office; approximately 455 pages, illustrated, 8 by 10½, $3 (paperbound) (scheduled for publication in April 1959)

This handbook is the third volume of the "Naval Reactors Physics Handbook," written for persons having some knowledge of the physics of nuclear reactors. It is an accumulation of physics information obtained from the work on intermediate-spectrum reactors at Knolls Atomic Power Laboratory. Wherever pos-

sible the material has been prepared by personnel who participated actively in the developments discussed.

In general, the material covers the importance of the properties of critical assemblies and of techniques for obtaining related experimental information; the uses of critical assemblies and reactor theory in making and testing predictions of reactivity variation during operation; the spread of heat generation in space and time; nuclear effects resulting from presence of beryllium or sodium in the reactor; the transient or near transit behavior of intermediate reactors.

Terminology of intermediate reactor physics which may not be familiar to persons who have dealt solely with thermal reactors is explained. References are listed conveniently at the end of the chapter in which they occur.

Contents: The physics of intermediate spectrum reactors. The critical assembly program. Design of critical assemblies. Inverse multiplication techniques. Methods of calibrating control rods. Activation experiments. Reactivity coefficient systematics. Reactivity coefficients and self-shielding measurements. Application of pile oscillation techniques to measurement of reactivity coefficients. Reactors survey calculations. Self-shielding calculations for SIR-type reactors. Statistical theory estimation of fission-product poisoning. A xenon calculation procedure adaptable to digital computers. Prediction of fission-product poisoning. Evaluation of SIR-type reflector control in critical assemblies. Burnable poison calculations for intermediate reactors. Critical assembly investigation of burnable poisons. Two-dimensional multigroup analysis of a SIR-type reactor. Estimation of reactor endurance characteristics by critical experiments. Loading, nuclear testing, and power operation of S1G. Power distribution measurements on critical assemblies. Gamma-ray and neutron heat generation. Gamma-ray heating measurements in the PPA. Decay heat and activity. Photoneutrons in beryllium-moderated reactors. Poisoning by Li^6 growth in moderator. Reactor kinetics and temperature coefficients. Isothermal temperature-coefficient measurements in the PTR. Calculation of temperature coefficients resulting from structural expansion. Temperature and power coefficients in the power reactor. Reactor thermal spectrum. The calculation of doppler temperature coefficients. Measurement of doppler coefficient by oscillatory heating. Critical assembly kinetics studies by oscillator technique. Measurement of power coefficients by pile oscillator. Temperature effects from rod-drop experiments. Method for comparison of temperature coefficient for rod-drop and pile oscillator experiments. Analog calculation of a runaway.

Appendix III–C

Titles for Prospective Books

1. "Fast Reactor Technology." [1]
   Volume I—"Fast Reactor Theory and Core Design."
   Volume II—"Fast Reactor Plant Design."
2. "Commercial Nuclear Ship Propulsion." [1]
3. "Reactor Control Systems."
4. "Atomic Energy Facts"—a revision.
5. "Sourcebook on Atomic Energy in the Biological Sciences."
6. "Nuclear Technology for Reactor Operators and Maintenance Technicians."
7. "Mathematics for Nuclear Engineers."
8. "Industrial Uses of Isotopes."
9. "Hydrides"—a handbook.
10. "Effects of Radiation on Chemical Reactions and Processes."
11. "Shipment of Radioactive Materials."
12. "Heat Transfer Problems in Reactor Design."
13. "Criticality Problems in Research, Manufacturing and Processing."
14. "Use of Electronic Computers in Reactor Design."
15. "Meteorology and Atomic Energy"—a revision.
16. "Handbook on Aerosols"—a revision.
17. "Reactor Materials for High-Temperature Applications."
18. "Small Power Reactors."

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[1] Already contracted for in fiscal year 1959.

Appendix III–D

PROCEEDINGS OF TECHNICAL MEETINGS AND SYMPOSIUMS PUBLISHED BY U.S. ATOMIC ENERGY COMMISSION IN 1958

"Papers Presented at the Reactor Fuel Measurement Techniques Symposium, Held at Kellogg Center, Michigan State University, East Lansing, Mich., June 18–20, 1958" (TID–7560); paperbound, $2.
"Proceedings of the 1958 Nuclear Merchant Ship Symposium, Washington, D.C., August 21, 1958" (TID–7563); paperbound, $2.50.
"Information Meeting on Gas-Cooled Power Reactors, Oak Ridge National Laboratory, October 21–22, 1958" (TID–7564); paperbound, $3.50.
"First Conference on Analytical Chemistry in Nuclear Reactors Technology," Gatlinburg, Tenn., November 4–6, 1957 (TID–7555); paperbound (two parts), $3.50.
"Proceedings of the Inter-American Symposium for the Peaceful Application of Nuclear Energy," Brookhaven National Laboratory, May 13–17, 1957 (TID–7554); paperbound, $6.
"Fixation of Radioactivity in Stable, Solid Media" (TID–7550); paperbound, $2.50.
"Fuel Elements Conference, Paris, November 18–23, 1957" (TID–7546); paperbound, $7.
"Reactor Safety Conference, New York City, October 31, 1957" (Pt. 2, TID–7549); paperbound, $1.
"Proceedings, International Conference on the Neutron Interactions With the Nucleus, Held at Columbia University, New York, N.Y., September 9–13, 1957" (TID–7547); paperbound, $3.25.
"Fifth Atomic Energy Commission Air Cleaning Conference, Held at the Harvard Air Cleaning Laboratory, June 25–27, 1957" (TID–7551); paperbound, $2.
"Design, Construction, and Operation of Engineering Test Reactor" (TID–7552); paperbound, $2.50.
"Proceedings of the SRE–OMRE Forum Held at Los Angeles, Calif., February 12–13, 1958" (TID–7553); paperbound, $3.
"Papers Presented at the Controlled Thermonuclear Conference," held at Washington, D.C., February 3–5, 1958 (TID–7558); paperbound, $4.75.
"Fifth International Congress and Exhibition of Electronics and Atomic Energy," held in Rome, Italy, June 16–30, 1958 (U.S. papers only) (TID–7557); paperbound, $1.50.

Appendix IV–A

TECHICAL MONOGRAPH TRANSLATIONS PUBLISHED BY U.S. ATOMIC ENERGY COMMISSION IN 1958

"Constructive Theory of Functions."
"Physical Chemistry of Pyrometallurgical Processes."
"Theory of Stability of Motion."
"Reviews on Radiobiology."
"Use of Radioactive Isotopes in Metallurgy Symposium XXXIV."
"Tagged Atoms in the Study of Plant Nutrition and Use of Fertilizers."
"Problems of Heat Transfer During a Change of State."
"Lithium and Its Alloys."
"Many-Particle Theory."
"Using Radioactive Carbon C^{14} in the Study of Photosynthesis."
"Energetics of Nuclear Reactors."
"Nuclear Energetics."
"Equations With Variational Derivatives in Problems of Statistical and Quantum Theory."
"Egyptian Atomic Energy Commission—Its Formation, Constitution, and Program."
"Research in Physics of High Energy Particles at the Synchrocyclotron of the Laboratory of Nuclear Problems of the Joint Institute for Nuclear Research."
"Propagation of Electromagnetic Waves in a Plasma."

Appendix VII–A

Domestic Depository Libraries

Alabama:
- Auburn, Alabama Polytechnic Institute Library.
- Birmingham, Birmingham Public Library.

Arizona: Tucson, University of Arizona Library.
Arkansas: Fayetteville, University of Arkansas Library.
California:
- Berkeley, University of California General Library.
- Los Angeles, University of California Library.
- Menlo Park, Stanford Research Institute.
- San Diego, San Diego Public Library.

Colorado: Denver, Denver Public Library.
Connecticut: New Haven, Yale University Library.
Delaware: Newark, University of Delaware Library.[1]
District of Columbia: Washington, Library of Congress.
Florida:
- Coral Gables, University of Miami Library.
- Gainesville, University of Florida Engineering Sciences Library

Georgia: Atlanta, Georgia Institute of Technology Library.
Illinois:
- Chicago, John Crerar Library.
- Chicago, University of Chicago Library.
- Evanston, Northwestern University Library.
- Urbana, University of Illinois Library.

Indiana:
- Indianapolis, Indianapolis Public Library.
- Lafayette, Purdue University Library.

Iowa: Ames, Iowa State College Library.
Kansas: Manhattan, Kansas State College Library.
Kentucky:
- Lexington, University of Kentucky Library.
- Louisville, University of Louisville Library.

Louisiana:
- Baton Rouge, Louisiana State University Library.
- New Orleans, Tulane University Library.

Maryland:
- Baltimore, Johns Hopkins University Library.
- College Park, University of Maryland Engineering and Physical Sciences Library.

Massachusetts:
- Cambridge, Harvard University Library.
- Cambridge, Massachusetts Institute of Technology Library.

Michigan:
- Ann Arbor, University of Michigan Library.
- Detroit, Detroit Public Library.

Minnesota: Minneapolis, University of Minnesota Library.
Missouri:
- Kansas City, Linda Hall Library.
- Rolla, The University of Missouri School of Mines and Metallurgy Library.
- St. Louis, Washington University Library.

New Jersey: Princeton, Princeton University Library.
New Mexico: Albuquerque, University of New Mexico Library.
New York:
- Buffalo, Lockwood Memorial Library.
- Ithaca, Cornell University Library.
- New York, Atomic Industrial Forum.
- New York, Columbia University Library.
- New York, New York Public Library.
- Rochester, University of Rochester Library.
- Schenectady, Union College Library.
- Troy, Rensselaer Polytechnic Institute Library.

[1] Depository library established in 1958.

North Carolina:
Charlotte, Charlotte and Mecklenburg County Public Library.
Durham, Duke University Library.
Raleigh, North Carolina State College Library.
Ohio:
Cincinnati, University of Cincinnati Library.
Cleveland, Cleveland Public Library.
Columbus, Ohio State University Library.
Toledo, University of Toledo Library.
Youngstown, Youngstown University Library.
Oklahoma: Stillwater, Oklahoma State University Library.
Oregon:
Corvallis, Oregon State College Library.
Portland, Portland Public Library.
Pennsylvania:
Philadelphia, University of Pennsylvania Library.
Pittsburgh, Carnegie Library of Pittsburgh.
University Park, Pennsylvania State University, Pattee Library.
Puerto Rico: Rio Piedras, University of Puerto Rico, Main Library.
Rhode Island: Providence, Brown University Library.
South Carolina: Columbia, University of South Carolina, McKissick Memorial Library.
Tennessee:
Knoxville, University of Tennessee Library.
Memphis, Memphis Public Library.
Nashville, Joint University Libraries.
Texas:
Austin, University of Texas Library.
College Station, Agricultural & Mechanical College of Texas Library.
Dallas, Southern Methodist University Library.
Houston, The Rice Institute Library.
San Antonio, San Antonio Public Library.
Utah: Salt Lake City, University of Utah Library.
Virginia:
Blacksburg, Virginia Polytechnic Institute Library.
Charlottesville, University of Virginia, Alderman Library.
Washington:
Pullman, State College of Washington Library.
Seattle, University of Washington Library.
West Virginia: Morgantown, West Virginia University Library.
Wisconsin:
Madison, University of Wisconsin Library.
Milwaukee, Milwaukee Public Library.
Wyoming: Laramie, University of Wyoming Library.[2]

APPENDIX VII–B

FOREIGN DEPOSITORY LIBRARIES

Argentina: Buenos Aires, Comision Nacional de Energia Atomica.
Australia:
Canberra, Australian National Library.
Sutherland, Australian Atomic Energy Commission.
Austria:
Vienna, Institut fur Radiumforschung der Oesterreichischen.
Vienna, International Atomic Energy Agency.
Belgium:
Brussels, Centre d'Etudes pour les Applications de l'Energie Nucleaire.
Brussels, Euratom.[1]
Brazil: Rio de Janeiro, Instituto Brasileiro de Bibliografia e Documentacao.
Burma: Rangoon, Union of Burma Applied Research Institute.
Canada: Ottawa, National Research Council Library.

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[1] Depository library established in 1958.
[2] Id.

Ceylon: Colombo, University of Ceylon.
Chile: Santiago, Ministerio de Relaciones Exteriores.
China: Hsinchu, Formosa, National Tsing Hua University Library.
Colombia: Bogotá, Comision de Energia Atomica de Colombia.
Costa Rica: San Pedro, University of Costa Rica Library.
Cuba: Havana, Comision de Energia Nuclear de Cuba.
Denmark: Riso, Danish Atomic Energy Commission.
Dominican Republic: Ciudad Trujillo, Secretary of State for the Armed Forces.
Egypt: Cairo, Egyptian Atomic Energy Commission.
England:
Birmingham, Central Library.
Bristol, Central Library.
Kingston upon Hull, Central Library.
Leeds, Central Library.
Liverpool, Central Library.
London, Central Library Action.
London, Science Museum Library.
Manchester, Central Library.
Newcastle upon Tyne, Central Library.
Nottingham, Public Libraries.[2]
Sheffield, Central Library.
Finland: Helsinki, Teknillisen Korkeakoulun Kirjasto.
France:
Gif-sur-Yvette, Centre d'Etudes Nucleaires de Saclay.
Paris, Organization for European Economic Cooperation, Nuclear Energy Library.
Germany:
Berlin, Institut fur Kernforschung Berlin.
Frankfurt/Main, Gmelin Institute.[3]
Munich, Technische Hochschule, Bibliothek.
Greece: Athens, Greek Atomic Energy Commission.
Guatemala: Guatemala, Comision Nacional de Energia Nuclear.
Haiti: Port-au-Prince, University of Haiti.
Honduras: Tegucigalpa (U.S. Embassy).[2]
Iceland: Reykjavik, University of Iceland, Atomic Energy Library.
India: Bombay, Department of Atomic Energy.
Iran: Teheran (U.S. Embassy).[2]
Iraq: Baghdad, the Ministry of Development, Atomic Energy Division.
Ireland: Dublin, University College.
Israel: Tel Aviv, Israel Atomic Energy Commission.
Italy:
Milano, Comitato Nazionale per le Ricèrche Nucleari.
Rome, Comitato Nazionale per le Ricèrche Nucleari.
Japan: Tokyo, Science Section, Diet Library.
Korea: Seoul, Atomic Energy Section, care of Ministry of Education.
Lebanon: Beirut, American University.
Luxembourg: Luxembourg, Ministry of Transport and Electricity.
Mexico: Mexico, D.F., Comision Nacional de Energia Nuclear.
Netherlands: The Hague, Reactor Centrum Nederland.
New Zealand: Wellington, Department of Scientific and Industrial Research.
Northern Ireland: Belfast, Department of Industrial and Forensic Science.
Norway: Lillestrom, Institutt for Atomenergi.
Pakistan: Karachi, Atomic Energy Commission.
Peru: Lima, Biblioteca Nacional.
Philippine Republic: Manila, Interdepartmental Committee on Atomic Energy.
Poland: Warsaw, Office Commissioner of the Polish Government for Uses of Nuclear Energy.[4]
Portugal: Lisbon, Junta de Energia Nuclear.
Scotland: Glasgow, Mitchell Library.
Spain: Madrid, Junta de Energia Nuclear.
Sweden: Stockholm, Atomenergi AB.
Switzerland:
Geneva, CERN (European Organization for Nuclear Research).
Geneva, United Nations Library.
Zurich, Institut fur Physik, Eidg, Technische Hochschule.

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[2] Id.
[3] Id.
[4] Id.

Thailand: Bangkok, Office of the Thai Atomic Energy Commission.
Turkey: Ankara, Turkish Atomic Energy Commission.
Union of South Africa: Pretoria, South African Council for Scientific and Industrial Research.
United Nations: New York, N.Y., UN.. Headquarters.
Uruguay: Montevideo, Universidad de Montevideo.
Venezuela: Caracas, Instituto Venezolano de Neurologia e Investigaciones Cerebrales.
Yugoslavia: Belgrade, Federal Commission for Nuclear Energy.

Appendix VII–C

Classified Depository Libraries for Access-Permit Holders

California: Menlo Park, Stanford Research Institute.
District of Columbia: Washington, U.S. Atomic Energy Commission.
Idaho: Idaho Falls, Phillips Petroleum Co.
Illinois: Lemont, Argonne National Laboratory.
Massachusetts: Cambridge, Massachusetts Institute of Technology.
New York: New York, New York Operations Office, AEC.
Pennsylvania: Pittsburgh, Carnegie Library of Pittsburgh.
Tennessee: Oak Ridge, Technical Information Service Extension, AEC.

Appendix VIII–A

The professional level film list attached to this appendix is on file with the Joint Committee.

Appendix 8

Letter from James L. Grahl, of the American Public Power Association, on the problems associated with capital grants to utilities. (See also p. 143.)

American Public Power Association,
Washington, D.C., January 26, 1959.

Memorandum to: The Honorable Chet Holifield.
From: James L. Grahl.
Subject: Problems associated with capital subsidies to utilities.

This memorandum is submitted in response to your request during the seminar session which the Joint Committee on Atomic Energy held on January 16 with representatives of publicly and cooperatively owned power systems.

As I believe Alex Radin and I made clear during the seminar, the submission of this memorandum does not imply endorsement by the American Public Power Association of Federal capital grants to utilities to assist in the financing of nuclear powerplants. Our views as to the best way to accelerate and expand the atomic power development program were set forth most recently in our comments on the "Proposed Expanded Civilian Nuclear Power Program" which Mr. Radin transmitted to Mr. James Ramey by his letter of November 18, 1958.

You will recall that your request for a memorandum followed comments by several, including myself, that capital subsidies could induce serious distortions in the development of atomic power technology in the United States. This memorandum comments on the most obvious possibility and there may be others. The remainder of the memorandum discusses possible administrative difficulties, but probably is not a complete inventory of these.

Two problems not discussed in detail are those relating to (a) patent rights in connection with plants built with public subsidies, and (b) to utility rate regulation. It is not clear to me what the patent situation would be. In respect to utility rates, certainly utilities should not be allowed to include in their rate base

or operating expenses costs which are covered by public subsidies. This should be assured by Federal legislation.

EFFECT ON TECHNOLOGY

Capital grants would encourage the construction of plants with relatively high capital costs and low fuel, operating, and maintenance costs. In choosing the type of reactor to be proposed, there would be a strong tendency to propose those types characterized by high unit capital investment and low fuel costs; the Calder Hall type is an example. In designing a reactor of any type, there would be an equally strong tendency to spend money on capital investments whenever such additional investment promised savings in fuel or operating and maintenance costs even if such savings would not justify the additional capital investment required if there were no capital subsidy. For example, the use of heavy water and zirconium fuel cladding, both of which enhance neutron economy, probably would be artifically encouraged by capital subsidies.

If the Government were paying the difference, or a large part of the difference, between the capital cost of a nuclear plant and a conventional plant, and the utilities were paying all or most of the fuel, operating, and maintenance costs, these tendencies obviously would be strong and one could expect a corresponding distortion of the direction of power reactor development.

To minimize these effects of capital grants, it would seem essential that the AEC has responsibility for designating the specific types of reactors eligible for capital subsidies and for reviewing in detail and approving plant designs in each case before granting a subsidy.

However, in order to do an intelligent job of specifying the reactor types and sizes eligible for subsidies, AEC will need to develop and periodically revise a long-term power reactor development program of which the specified projects would represent elements. So far, AEC has not been able to do this. To do this program development job capably and to do an effective job of reviewing project designs and otherwise administering a capital subsidy program, AEC will need to have a highly competent professional staff substantially larger than its present staff in the Division of Reactor Development. Even with a large and competent staff, it probably would be difficult to prevent some degree of distortion of U.S. power reactor technology under a capital subsidy program.

ADMINISTRATIVE DIFFICULTIES

Several administrative problems seem likely with a capital subsidy program. These are summarized below:

1. The cost of a conventional plant, which presumably would be the base figure in computing the capital subsidy for any given nuclear power project, would have to be determined de novo in each case. There is no such thing as a "typical" unit cost for conventional thermal powerplants. An Electrical World tabulation of 1957 of modern steamplant costs reflects the wide range of unit costs; for example, in the case of two plants of 100–150 megawatts each, the unit cost for one plant was $99 per kilowatt whereas for the other it was $199 per kilowatt. The cost of a conventional plant varies widely depending upon geographical location, type, the degree to which supporting facilities already exist, market conditions in the steel and construction industries, et cetera.

To determine in each case what the cost would be of a new conventional plant on the system of the utility proposing a nuclear plant would not be a simple matter if the figure were to be fair to both the Government and the utility. It might be necessary to obtain competitive bids on a hypothetical new plant in order to ascertain this figure.

2. The cost per electrical kilowatt of the proposed nuclear plant is the other figure required to fix the amount of a capital subsidy. This poses more difficulties than establishing the cost of a hypothetical conventional plant. First, an "average" cost per kilowatt would be useless in computing the subsidy for an individual plant as the costs of nuclear plants vary widely. Thus, one privately proposed nuclear plant is estimated to cost $1,300 per kilowatt; another is estimated at $333 per kilowatt. The unit cost would have to be established for each nuclear plant individually.

Second, the total nuclear plant cost can be only an estimate unless the utility can obtain a fixed and firm price from a manufacturer, and be sure that there will be no design change orders during construction entailing significant additional costs. It seems doubtful that either of these conditions could be met in

the case of a truly developmental plant. If a fixed price were quoted, it would have to include very large contingencies, meaning high fixed prices and unduly large capital subsidies. No obvious or easy answer to this problem is apparent.

Third, the capacity of a developmental nuclear plant is an estimate, usually well on the conservative side. If the plant should prove to have a larger capacity than estimated, as is likely, its per kilowatt cost of course would be reduced accordingly. This larger capacity and lower unit cost might be demonstrated during plant operation with the first core and additional increases in capacity might be achieved with improved second and third cores. The third core, however, might not be inserted until after the plant has operated for 5 or 6 years or more.

If the capital subsidy were made on the basis of estimated capacity, the consequence of a larger actual capacity would be a windfall to the utility. It therefore would be necessary to provide for renegotiation of the capital grant, with recalculation of the cost per kilowatt of the nuclear plant based upon its proven capacity, and recapture by the Government of the excess subsidy initially granted. Otherwise, the net cost of nuclear power to the utility might be even less than of conventionally generated power. The Government would need to have the right of renegotiation and recapture for a long period—10 years or possibly longer—after the subsidized plant went into operation.

Fourth, the Government would need to assure itself that the estimated costs of the nuclear plant were reasonable in the first instance. Presumably, this would require a detailed review by AEC of plant design and component cost estimates.

Fifth, having approved the subsidy, the Government presumably would want some assurance that the plant was built as economically as possible, especially if it had renegotiation authority. At a minimum, therefore, the Government would need to require open, competitive bidding on all plant construction and equipment. As a "partner" in financing the capital costs, the Government might need also to exercise some degree of inspection or supervision of design and construction. Presumably, at a minimum, sufficient AEC and General Accounting Office inspection and audit would be necessary to verify actual capital costs and exclude any improper costs in computing the Federal subsidy.

3. Another problem in administering capital subsidies would arise from the fact that where as utilities are primarily concerned with the total cost of power, the capital subsidy would relate to only one aspect—the fixed charges. The problem can be illustrated by a hypothetical example. Suppose a utility located in a high cost fuel area was awarded a capital subsidy covering all or a large part of the difference between conventional and nuclear plant costs, constructed the plant and found that, with the first or second core, they experienced fuel costs sufficiently below their conventional fuel costs that the total net cost of power to the utility was below the total cost of conventional power. The result would be a windfall to the utility.

To prevent this happening would require relating the capital subsidies not only to conventional plant costs but also to the relationship in each case between conventional fuel costs and nuclear fuel costs. Since the latter are highly uncertain this would have to be done initially on an estimated basis and then adjusted during the first 5 to 10 years of plant operation.

However, if capital subsidies were related to fuel cost considerations, they would then become general cash subsidies rather than strictly capital grants and additional complexities would be introduced into the administration and policing of the subsidy program. If they are not so related, it is entirely possible that for certain projects capital subsidies would result in financial windfalls to the sponsoring utilities.

If there is a satisfactory answer to this problem, it is not readily apparent.

OPEN SUBSIDIES OPENLY ADMITTED

It is obviously important that if Federal grants are made they be plainly labeled as public subsidies and that their existence and amounts not be hidden. The recipient utilities should accept responsibility along with the Government for informing the public of this.

In this connection, fuel subsidies should be handled differently than at present. The present practice of waiving the fuel lease charge hides the fact that a substantial annual public subsidy is to be provided to numerous "private" plants. Equally serious, this practice will tend to make private industry less concerned about minimizing the size of enriched fuel inventories in fabrication shops, re-

serve reactor cores, and the reprocessing pipeline, since the Government is paying the rental cost on this idle inventory.

It would be much healthier for the industry and encourage tighter fuel inventory management if industry were in every case to be charged the full 4 percent per year lease charge for all fuel, and any fuel subsidies given as cash grants from appropriated funds. The present practice not only encourages loose inventory management but hides the amount of the subsidies being given and evades the regular appropriations process. The costs of the subsidies are significant but under present practices they do not show up in AEC's budget or program costs.

SUBSIDY TERMINATION

Finally, with any capital subsidy program, there would be the inherent difficulty of terminating it. To say that capital subsidies would end with the end of the developmental phase of nuclear power does not mean that the program would terminate in the foreseeable future. It is abundantly clear that before one type of power reactor is out of the developmental phase, numerous others of presumably superior promise are conceived and their development initiated. This will continue to be true for the foreseeable future.

The Joint Committee "Proposed Program" sets a goal of demonstrating economic nuclear power in the United States by 1970, so it seems safe to assume that a capital subsidy program would continue for at least the next 10 years. However, by the time it appears that one or more reactor types are economic, there surely will be concepts ready for development which promise cheaper power if sufficient development and prototype construction are performed. Assuming this kind of continuing situation, the difficulty of terminating capital grants and persuading industry to shift to financing its own developmental prototypes can be readily imagined.

APPENDIX 9

SURVEY OF U.S. INDUSTRIAL PARTICIPATION IN THE ATOMIC ENERGY INDUSTRY

[From Facts for Industry, U.S. Department of Commerce, for release, Apr. 27, 1959]

ATOMIC ENERGY PRODUCTS, 1957

During 1957, shipments to U.S. Government agencies, to export, and to others, of selected key atomic energy products manufactured in privately owned establishments totaled $100 million. These included shipments of radiation detection and monitoring devices valued at $17.5 million; reactor vessels and tanks valued at $11 milion; accessory instrumentation for reactor control at $9.5 million; complete reactor fuel elements shipped directly for installation or use in a reactor valued at $8.6 million; heat exchangers, valves, and pumps uniquely designed for nuclear applications valued at $8.3 million, $7.8 million, and $6.2 million, respectively; control and measuring devices containing radioactive isotopes valued at $6 million; and nuclear reactors completely assembled at the place of manufacture, valued at $5.7 million. Also included are shipments data for the following products specifically designed for use in nuclear applications: reactor control rod drive mechanisms; partially fabricated fuel materials (not shipped directly for installation or use in a reactor); core structures; hot laboratory equipment; radioactive isotopes (shipped from plants producing isotopes); radiation sources and other radioactive materials (produced from purchased isotopes); and pressurizers and other specialized reactor components.

The data published in this report were developed from a survey MA–38Q, "Atomic Energy Products Shipments Report for 1957," jointly sponsored by the Bureau of the Census and the Atomic Energy Commission. Data were included from all known manufacturers of selected products specifically designed for use in nuclear applications. Excluded are construction expenditures, engineering and design costs, research and development expenditures, as well as shipments data for products used in atomic energy work which are not uniquely designed for nuclear applications. Comparable data for earlier years are not available.

Inquiries concerning these data should be addressed to the Bureau of the Census, Industry Division, Washington, D.C.

Shipments of atomic energy products: 1957

Product	Value of shipments ($1,000)		
	Total	U.S. Government agencies	Other, including export
Total	100,106		
Nuclear reactors	5,709	(1)	(1)
Reactor components and equipment:			
Reactor vessels and tanks	10,955	10,105	850
Reactor control rod drive mechanisms	1,263	722	541
Accessory instrumentation for reactor control	9,501	6,319	3,082
Heat exchanges	8,284	7,925	359
Pumps	6,201	5,509	692
Valves	7,771	6,201	1,570
Pressurizers and other specialized reactor components	4,919	3,856	1,063
Complete reactor fuel elements shipped directly for installation or use in a reactor	8,567	8,139	428
Partially fabricated fuel materials not shipped directly for installation or use in a reactor	4,864	(1)	(1)
Core structurals (barrels, cans, boxes, plates, etc, not included above)	948	769	179
Hot laboratory equipment	4,761	2,540	2,221
Radiation detection and monitoring devices	17,471	8,422	9,049
Radioactive isotopes shipped from plants producing isotopes	73	(1)	(1)
Radiation sources and other radioactive materials produced from purchased isotopes	2,722	418	2,304
Control and measuring devices containing radioactive isotopes	6,007	(1)	(1)

[1] Withheld to avoid disclosing figures for individual companies.

Source: Prepared by the Bureau of the Census, Industry Division, Machinery and Equipment.

APPENDIX 10

RADIATION COUNTER LABORATORIES, INC.,
Skokie, Ill., April 1, 1959.

Subject: Wall Street Journal quotation of March 23, 1959.

Hon. CLINTON P. ANDERSON,
U.S. Senate, Washington, D.C.

DEAR SENATOR ANDERSON: The nuclear instrument industry can be profitable despite the statement to your committee by Samuel S. Auchinloss, president of Tracerlab, printed in the March 23 issue of the Wall Street Journal. Radiation Counter Laboratories, Inc. (RCL) for the fiscal year 1958 had a return on capital before taxes of 133 percent on sales of $1.7 million. Nuclear-Chicago [1] for the same fiscal year had a return on capital of 83 percent on sales of $3.8 million. These two companies are believed to have done 12 to 15 percent of the total nuclear instrument business in the United States for that year.

In the subsequent 6 months incoming orders for RCL were up 36 percent over the preceding 6 months, while Nuclear-Chicago had a gain of 50 percent. These figures would indicate that with present economic conditions and Government regulations, the nuclear instrument industry can take care of itself, if its managers take care of it.

A copy of this letter is being sent to Mr. Auchinloss to inform him that his testimony recommending that Government increase spending on education in industrial use of isotopes in order to make the nuclear industry profitable, is unnecessary.

I oppose the statements of Mr. Auchinloss because his recommendations can lead to less corporate freedom—a freedom which has given America the highest standard of living in the world.

Sincerely yours,

ERNEST H. WAKEFIELD, *Director.*

[1] All Nuclear-Chicago figures are deduced from official statements issued.

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